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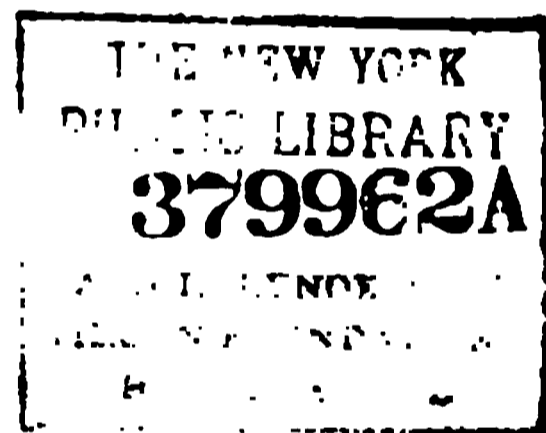
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THE ENGINEER AND HIS WORK.

Prof. W. F. M. Gross, M. E.

The impression produced by terms employed in conversation or discourse, depend in large measure upon the experiences of those to whom they are addressed. If, for example, it had been announced that I was to speak to you of the philosopher, every one present would have a rather definite conception of my theme, for the philosopher has lived and wrought for centuries, and all civilized people know something of his work. Unlike the philosopher, the engineer is a product of modern times, and the public is not well acquainted with his methods or purposes. People see in the increasing complications which attend the modern life, many evidences of his presence, but of the engineer himself, they know but little. It is in recognition of this fact that I have chosen to speak to you of the engineer and his work.

Beginning with Watt and the two Stephensons about a hundred years ago, the progress of the engineer has been continuous and marvelously rapid. During this period, he has ushered in the era of steam, of steel, and of electricity, and has made them to become foundation stones in our present civilization. He has built up the whole fabric of material things by which we travel or otherwise extend our communication. He digs vast mines and draws forth their hidden wealth of fuel and ores. He surveys and determines the way, he cuts through hills, pierces mountains and bridges streams that ponderous trains moving with a velocity greater than that of the wind, may bear their burdens safely from city to city and from ocean to ocean. He builds in stone, and a river is stopped that it may do his work, or a monument is built, or a beacon is raised by the sea, which through the certainty of his art becomes fixed for centuries. When buildings are to be

warmed, the engineer designs and specifies, the equipment thus defined is installed and the object sought is accomplished. When great electrical effects are demanded, he converts the road of water-fall into light. Such enterprises are not the fruit of dreams nor do they stand by chance. A study of conditions, and a vision of people's need suggests them, and exact and laborious processes serve to develop every detail of the general plan. To conceive enterprises and to develop them is the part of the engineer.

Many things which today are accepted as commonplace are the result of severe and patient labor on the part of the engineer. This is especially true of structural shapes in steel which enter largely into the upbuilding of so many modern structures. The I-beam, for example, enters alike the frame of an office building or that of a trans-Atlantic liner. It is of simple outline, but its production represents engineering processes which are long and complicated. Think of the handling and transportation of ores, of huge blast-furnaces with their great pumps driving forward the air to urge their fires; of layers of coal and of ore filled in at the top and settling down to the melting zone of the furnace, of ladles carrying in a single mass a score of tons of melted iron, of the flame which roars from the mouth of the converter, as the boiling metal is purged of its impurities and changed from iron into steel; of the flow of the newly made steel into molds; of rose-hued ingots moving on to ponderous rollers between which it is made to pass and repass until the desired section is formed. And, having witnessed the result, think of the life and energy of Bessimer and of Siemens whose investigations gave the process, and of all the world's great engineers who have labored to perfect its details until steel mills with their vast furnaces and complicated machinery go on interrupted day and night, week after week until months become years, making steel more cheaply than iron. Think of these things and you will see that even a common I-beam, simple as it appears to be, exists as the result of the devotion of great men and these men are engineers.

It happens, of course, in this day of specialization that no man is expert in all of the several departments of engineering. There are mechanical engineers, who deal with steam and shop machinery; electrical engineers who are concerned with generators, motors and transmission lines; civil engineers who locate railroads and build bridges; municipal engineers who design systems of

water and sewerage; and so on through a vast field of industrial activity. One of the omre recent distinctive terms which has appeared is that of "modernizing engineer," whose function is, I presume, to make old things new.

A concise definition, makes the engineer anyone whose function it is to combine the principles of the scientist with the money of the capitalist in the production of material things.

With this understanding of what an engineer does, we may next inquire concerning the manner of man he is. First of all, we must note that he is exceptional in the training he has received, for the engineer of today has reached his present station by a long and laborious process. As a youth, he has persisted in the work of his school, and has held to his task when many of his fellows, having equal opportunity, have yielded to boyish desires and have dropped out to become wage-earners. A youth must be something more than ordinary who, at the close of his grammar school, can see the ranks about him thin and again at the conclusion of his high school course, see many others drop away and yet hold in check his natural restlessness and enter resolutely upon a four years' college course. Nor is such a career made easy for him! All along the way he is subjected to severe tests designed to prove his worthiness to proceed. In the high school, at the entrance gate of the college and throughout his college course, obstacles have been placed in his way. Men all about him have failed and departed while he, by virtue of his manly qualities has passed on. Many of those who were his companions, having proven themselves stupid, or lazy, or indifferent, or of bad habits, have been shaken out with the result that he and his fellows stand on commencement day as winnowed products. By this I do not mean that he is better than other men or that he is entitled to more consideration, but rather that he has given proof of the possession of certain high qualities of character which are not possessed by all men.

wish to be understood as implying that all such graduates are or

In paying this tribute to the technical graduate, I do not will ever become engineers in the full sense in which I use that term. Many such graduates, responding to opportunities which are presented to them, turn from work that is strictly technical and enter upon business or other careers, and in this, if they follow their tastes, they doubtless do well; others are content to

drift and soon find their pace with the slow moving tide about them, and while working at engineering, never become engineers; still others, through the possession of positive defects of mind or character are prevented from achieving the results of a master. But he whose career we follow is not to be side tracked or stopped. Building upon past experiences, he proceeds with his work, assuming responsibilities which at first may be unimportant but which gradually become of greater significance, he attains to those attributes of character and becomes familiar with those lines of action which mark the true engineer. His characteristics are simple, perhaps even homely, but of such importance as to make it worth one's while to consider briefly their nature.

First of all, our engineer is accurate, both in speech and in work. As the machine which he creates performs over and over again with unerring precision the operation for which it is set, so he, the creator of the machine, must proceed in all things with accuracy. It is his part to make reports which are to guide his clients, it may be, in reaching a decision as to the soundness of propositions involving matters which are technical; or he is required to draw specifications which will govern in the expenditure of large sums of money; and both the report and the specifications must be expressed in language which defines with accuracy. It is for this reason that the engineer carefully prepares himself for accurate and effective writing, for however well the foundation for a specification may be prepared, it will be valueless unless the written requirement is clear.

Many things contribute to his training in this particular, from among which I venture to name three. These are the language training of the college course, general and technical reading and an interest in things outside of his own course and profession. The modern engineering student too frequently regards as of little importance anything which is not closely related to the technique of his own course. This disposition prevents him from appreciating the language training of his course which if well administered can not fail to be more useful to him in his future work than much that is severely technical. Again, every engineer should know a great deal about much that has been written. He should before graduating have read Samuel Smiles' "Lives of the Engineers," many of the text books of the science series, much of the Proceedings of engineering societies, and

some of the technical papers. This not only increases his fund of information but contributes to the strength and accuracy of his writing. Again, by being interested in affairs outside of his course, he comes in contact with men who are different in their preparation and in their trend of thought and this brightens a new side in his own personality which gives lustre to his own life.

Again, as he regards as important the accuracy of speech and of written words, so also must he prize the element of accuracy which marks his scientific processes. His professional reputation rests upon this. The public will have no confidence in him unless they can feel that his theories are sound and his application of them correct. A remark which I once heard made concerning Sir Benjamin Baker, the designer and one of the builders of the great Forth bridge, illustrates this point.

The Forth, as you know, is a broad arm which the North Sea thrusts into the eastern side of Scotland. At the crossing point, it is nearly a mile in width. Above this broad bay stands the great bridge with its approaches more than a mile and a half in length but so high and so vast that the contemplation of it from the shore makes the Forth shrivel and seem small until the passing of a steamer, a mere fleck upon its surface, helps one to measure distances at their real value. It was at a meeting of engineers that a new-found friend called my attention to Sir Benjamin's presence at the other side of the room, saying of him "He designed the great Forth bridge not by proxy but to the extent of calculating *himself* the stress in every part." Whether this was strictly true, I can not say, but the remark constitutes one of many evidences which are to be met with by the traveler in England, testifying to the public confidence in the painstaking and accurate methods of the designer of the great bridge.

Closely akin to accuracy in work, is fidelity to the truth. Our engineer above all else is truthful! His is not that truthfulness which consists in not telling lies for such a negative virtue is at once recognized by him as insufficient for his station. In a scientific sense, he is required to be a revealer of truth. He is required to analyze propositions for investing money on the part of those desiring a return for their investment. He must ascer-

tain the cost of the undertaking and must decide as to its effectiveness when completed. His investigations lead him to fundamental facts which he is powerless to change or to set aside, and in view of these, his judgment must be rendered. Evidently, the value of the conclusions depends upon the degree of fidelity with which the engineer adheres to his facts. In the little affairs of business, also, he always means what he says. Our engineer who has need of a coil of rope does not ask for three coils with the expectation that his estimate will be cut, and that in the end he will get about what he needs. His method is to study well his requirements, to ask for nothing until he knows just what must be supplied, and his requisition goes in as a matter which he can defend. He recommends no purchase because a friend has something to sell, and has no pecuniary interest in anything which is bought. Because of his painstaking method in their preparation, his requisitions carry conviction with them. No man can be an engineer whose yeas are not yeas or whose nays are not nays.

But the course of the engineer is not always plain before him. He sometimes stands between powerful interests which conflict. Having charge of some important work, it may be proposed to substitute a new material for that specified or new details for those shown by the drawings. A contractor may urge that the material specified is difficult to get while that proposed is at hand; that by making the change, the proposed work can be advanced rapidly, whereas otherwise there must be long delays. The engineer informs himself fully concerning every bearing of the question, and gives his decision. But it often happens that after he has done his best to secure an equitable adjustment, the matter is not settled especially if by chance the decision goes against the contractors. They may importune his employers for a consideration. They may work on the minds of timid investors until the very parties in whose protection the engineer gives his decision question the wisdom of his action and give moral support to those who propose supplying them something inferior to that for which they have agreed to pay. Under all such trying conditions, the true engineer does not often fail to protect his work and his clients, not through stubbornness or mere force of will, but by his own integrity, by the care which he has taken each step and his ability to show evidence of the justice which underlies his decision.

Enough has been said to show that the part of the engineer is not always an easy one. Devotion to a cause always brings its sacrifice. The engineer who develops a principle may proceed ever so carefully and yet pass many sleepless nights between the complete theoretical development and finished structure or system. Difficulties arise not because the principle is bad but because of numberless necessities which are developed when it is sought to apply the principle. Occurrences which he had expected and which he may have planned to guard against, and which are in fact but incidents, may be looked upon by the uninitiated as a failure of the principle itself. And so it is that the engineer is required to labor long and patiently, convincing his supports that he is right, modifying details, here a little, there a little, always as one who is tireless until the desired result is reached. It not infrequently happens that he must give evidence of his devotion by the exercise of unusual physical exertion. For example, in the construction of the arched bridge across the Mississippi at St. Louis, the erection was advanced without the aid of false work. Beginning on each side of each pier and at each abutment the high tubes of which the steel arches are composed, were built outward, supported by cables which were carried over the top of the tower. Thus supported, the arches were permitted to grow upward and outward, until each span extending from either side was made almost to meet high above the water midway between piers. Thus sustained, the free ends changing their positions with every change in temperature, the problem of inserting the last length in each of the four lines of arch tubing became a matter of extreme delicacy. It was important also that when one tube had been closed, the others be completed as rapidly as possible in order that that portion of the structure might not be overstrained as a result of the partial support. In closing the first span, the engineer in charge (Mr. Cooper), and many of his men were constantly on duty for a period of sixty-five hours. In writing of the experience, Mr. Cooper said: "We were so sleepy that it was almost impossible for us to keep our eyes open and I was much afraid that some of us would go into the river." Such is and always must be the engineer's devotion to his trust.

It is in this wise that the true engineer holds himself to his work. He has need of no task-master or time-piece. His incentive to work is a desire for useful results and in their produc-

tion he combines and sends forth all the energy that he can command.

Again, it is not sufficient for the engineer to have training, to be accurate, to be a man of truth and integrity, and to be devoted to his trust. These are high qualities but he must have more than these. Especially must he be resourceful. He must have much of a quality which is akin to inspiration. His conceptions must carry him from the thing accomplished to possibilities of which other people have not dreamed. In its fullness, this attribute is a rare gift. It is a birthright; it is not often acquired. One can not design a bridge or a dam unless the essential elements of the structure are complete in his imagination before he commits them to paper or material. There can be no large structure without a man who is capable of entertaining large conceptions. When Captain Eads, from his knowledge of the habits of rivers, had conceived the plan by which the channel of the Mississippi might be deepened, he saw all features of the construction just as they were afterwards developed in actual materials. Here moved the water of a mighty river in a shallow current spread out over a wide course. There was need to meet the requirement of commerce, a channel of considerable depth. The vision of the engineer made clear the fact that the water if confined to a narrow course must work its way deeper into the sandy bottom. All along the bank grew willows in abundance. The engineer saw the willow branches cut, woven into great mattresses, and then loaded with stones and sunk, one after another, along the course of the stream, layer upon layer, until willow twigs and stems, intermixed with sand deposited by the water extended from the bottom of the stream to the surface, forming a supplemental bank between which the contracted stream rushed rapidly, cutting its way downward and giving the desired channel. The plan is not complicated and the completed work seems simple enough. But without the inspiring genius of the great engineer, the Mississippi might today be rolling its slow, shallow and wide reaching way.

Thus far, attention has been given those qualities of character which mark the true engineer. We have now to consider the nature of the field in which these qualities may be exercised. Speaking in very general terms, this as I conceive it, is a two-fold one. It may involve technical functions only, or it may con-

sist largely of business functions growing out of technical information and experience. For example, by acting the part of a consulting engineer, he designs special apparatus or examines and criticizes the designs of other people and in general advises clients with reference to matters that are purely technical. Or, if the mechanical engineer of some large industry, he plans and specifies concerning extensions of work, or improvements in methods of production. In either case, his work is strictly technical. His relations to those who employ him are much the same as those of a doctor of medicine to his patients. The service calls for high moral and professional qualities, and when one's tastes and preparation adapt him to the service, such work leads to few perplexities. He finds in such a life a variety of work which is stimulating, while the professional character of the problems challenges his ambition. Such occupations attract men of the highest quality.

It is, however, to be questioned whether one who confines himself to problems which are purely technical represents the highest type of the engineer for a technical proposition or proof is after all a preliminary to a business organization which can execute it and make it effective in serving mankind. Thus it is that there has come to be a class of men who have recently been designated by one of their number as industrial engineers. Men who, while engaged in business pursuits, would be unable to perform the functions of their office did they not possess the technical training and accomplishments of the engineer. Such men are to be found at the head or near the head, of large manufacturing establishments and of great contracting firms. Their problems are those of organization and of pure business, but within them are conditions involving technical foresight of the highest order. The industrial engineer does not handle the instruments of the engineer but he employs men who give their time to such work and their conclusions constitute a part of the working material with which he deals.

I am often asked concerning the remuneration which an engineer receives, and as this serves as an indefinite measure of the degree of public esteem in which he is held, some reference to it will aid in my definition of the man. First of all, an engineer does not acquire riches because he is an engineer! The science of engineering is no royal road to competency! A man who enters the field for what there is in it will probably not succeed in find-

ing very much. As in other professions, his reward depends upon the importance of the problems in hand, and upon the extent of the responsibility which he assumes. There is much to be said in favor of the man who, having a good education, prefers to occupy himself with the working problems requiring a high order of technical skill and who so enjoys the process as to prefer the quiet of his office to all things else. There are many such engineers and they perform a useful part in the world's work. But however skillful they may be, they are not often highly paid. They are animated circulating machines and it is not difficult to fill their place. That which gives earning capacity is a willingness to accept new responsibilities and the ability to discharge them well when once assumed, and this willingness and this ability sooner or later lead one from the technical toward the business. My advice to young men who desire as an engineer to make the most of life is to seek every opportunity which may lead to the winning of new responsibilities. If you young men desire the highest professional success, you should study well the methods of your superior and find new ways in which to serve him. If you can relieve him a little at this point and more at that point, your progress will be assured. Count nothing as extra. It makes no difference whether you are paid for all you do, for that which as a young man you should most desire is responsibility, and as the load comes upon you, and you feel its added weight, hold yourself true to your purpose, for therein lies your chance.

But while responsibility and position are matters of great importance, they are not in themselves an end. It is not the salary or position that chiefly concerns the true engineer, though both may come to him. He asks first of all for a chance to serve, for while we are slow to recognize it, the engineer is in fact a servant of the people. Not only are his ingenuity and skill the starting point which leads to the employment of all the artisans who fill our shops and factories, but the constancy of their employment and their welfare depends largely on his management. Here stands the industrial engineer in full command of a great manufacturing establishment. He looks about him and sees thousands whose faces are lighted by the glow of his fires, all working at his command; and he thinks of other thousands who constitute the families of those who toil, for the comfort and happiness of all of whom he feels responsible. He turns to the

other side and locks out upon the market for his product. Whether it is weak or strong, he knows, and he lays his course according. If he fails to rightly interpret the signs of the time, or if he expands where he ought to economize, his establishment must lose and in the end mouths must go unfed. Thus it is that while our industrial engineer may have a large salary, it is not for this that he travels when other people rest, that his hours are longer than those of his most menial serving man, or that for a large share of his time, he abandons the cheer and comfort of his home for hotel corridors in many cities where business is talked. I repeat that it is not for mere salary that he does these things! It is because he feels that the success of a great business depends upon his effort. He sacrifices that he may achieve for the owners of his works who have trusted him, and for those whom he employs who follow his leadership.

Again, the engineer may connect by a bridge two cities on opposite sides of a flood, and may receive pay for his work, but as he designs that bridge, line by line, and superintends its erection member by member, his ideal extends far beyond a consideration of the fee he is to receive. He is serving a community of people; that as decades pass and generations of people make use of that way, the value of the service rendered will far exceed that of any fee which he may receive. He knows that it is his part to build well that all who come after him may rejoice.

It is this ideal of service which qualifies and ennobles the work of the true engineer; of service founded upon the sacrifice of all that is low or commonplace, and having throughout it all a fine integrity and lofty devotion to trust, a service that never tolerates neglect of those who are above nor permits injustice toward those who are dependent; a service which, while self sacrificing, will never fail to bring a full measure of useful results.

This then is my message to you who as students in the halls of this great institution of learning, are seeking to prepare yourselves for the work of an engineer. I have brought you ideals which are high but not impracticable. They are high because anything less would be unworthy. In so far as you succeed in living these ideals, just so far will your lives partake of that element which is best called greatness. And finally I would add that this is a matter of today, not of tomorrow. No man ever

accomplished anything worth doing by continual postponement of the day of its beginning. Many of you, by enrolling yourselves as students, have already entered upon a career as engineers, and the responsibility is upon you to give evidence of the possession of those attributes of character which in their fullness characterize the ideal engineer.

The Lighting of Lincoln.

Finances of a Municipal Enterprise.

C. R. Richards and G. H. Morse.

There was in the design and construction of the Lincoln Municipal Electric Lighting Plant, little of novelty save the thoroughly systematic manner in which this public undertaking was carried out. While the engineers were closely limited as to possible expenditure, their designs and recommendations were from the start followed, practically without exception. There resulted a wide and close competition, based upon carefully prepared plans and specifications which covered every detail of the plant and line equipments, as it stands, completed.

The engineers' estimates were, for plant building and chimney, \$13,138.00, and for all other parts, including power house equipment, pole line wiring and lamps, \$66,528.00.

The competition was widely advertised in the leading technical papers for several weeks prior to the letting. Practically all of the manufacturing companies in the country, making the required class of apparatus, as also many independent contracting concerns, were represented. After public opening of the bids, the various proposals were arranged, for purposes of easy comparison, in the form of a table which follows. The choice of two units as against a single unit, as also the three phase system was determined by certain requirements in connection with ultimate application to motor driven pumps in the city water works.

Fig. 1

THE POWER HOUSE AND CHIMNEY.

(Figures 1 and 2.)

The power house is a building of simple yet not **unattractive** lines, designed to be constructed at the lowest cost **consistent** with durability and adaptability to its purpose. The design is **one** which renders future additions easy, without interfering with the original installation of machinery.

Fig. 2.

The engine room is 40'x56' inside, and the level of the main floor is about 4' above grade; below the main floor there is a basement room with a clear head space of 7', to be used for storage, for a repair shop and for the wiring conduits from generators to switchboards, together with the field rheostats, power transformers, etc. The engine foundations (Fig. 3) built of solid concrete, reach from the floor of this basement to the main floor of the engine room. The main engine room floor is made

Fig. 3.

of a 5" concrete slab, reinforced with Kahn trussed steel bars: steel I beams resting on the side walls and the engine foundations, support the floor. The basement is floored with wood.

The boiler room is symmetrical in size with the engine room. the level of the floor being the same as that of the basement under the engine room. The room is paved with hard burned paving brick. Adjoining the boiler room, a coal and ash storage room 14'x56' is provided, the roof of which is made of reinforced concrete. The level of the floor in the boiler and coal storage rooms were placed for enough below grade to permit coal to be shoveled from ordinary coal cars through man-holes in the roof of the bins. At one end of the coal bin, a Jeffrey Mfg. Co's ash elevator, driven by a 5 h. p. motor, is placed.

The building is constructed of two pound pressed brick on.

the exterior, with three pound pressed brick on the interior of the walls, and common hard burned brick for filling. Below the water table the brick is laid in 1:3 Portland cement mortar; above this point the same mortar with 10% lime paste added was used. The original specifications called for Bedford stone water table, coping and sills, but to reduce the cost, artificial stone was substituted for the Bedford stone in the building, and all stone except the water table was omitted from the chimney.

The roof is supported by wooden trusses (Fig. 4) of the simple king rod type. In the original design of the building the underside of the roof covering was to be ceiled, and the roof cov-

Fig. 4.

ered with slate. To reduce the cost, common rafters were dressed and exposed, and the sheathing made of 6" matched flooring, covered with building felt and galvanized iron roofing painted on the out side. Monitors are placed over both the engine and boiler rooms, the former being provided with swinging windows operated from the engine room floor, the latter with fixed louvres.

The chimney is 4' 6" inside diameter by about 130' in height above the grates. The foundation is of 1:3:5 concrete, made with Portland cement, and is 20'x21' 6" on the ground, built in steps 1' thick to a height of 5'; at the point where the brickwork begins the foundation is 16' square. Near the bottom of the foundation a double row of old street car rails, laid cross-ways, was placed. While these rails were not considered essential, they were owned by the City, so were available without expense.

and it was felt that they would give added strength to the structure. The base of the chimney is square in section for about 20' and round for the remainder of the height, this part having a batter of about 1:40. An inner core wall with a dead air space between it and the outer wall, extends to the top of the chimney thus fully protecting the outer wall against cracking from unequal expansion. The core wall is lined with fire brick for about two thirds of its height and with common brick the remainder of the distance. The top of the chimney is finished with a heavy cast iron cap, and iron ladder rungs are built into the brick work of the core wall, from its bottom to the top of the chimney. Four copper lightning rods are screwed into the top of the cap, and a 3/8" copper cable is connected to this cap and grounded to a large copper plate, to afford protection against lightning.

The chimney is of sufficient size to carry about double the present capacity of the plant.

The engineers' estimates of the cost of the building and chimney were as follows:

BUILDING.

| | |
|--|-------------|
| 700 yds excavation at 30c | \$210.00 |
| 30 yds concrete footings at \$6.00 | 180.00 |
| 249 M brick laid, at \$13.00 | 3237.00 |
| 273 cu. ft. cut stone at 1.75 | 477.75 |
| 175 yds. plastering and pitching at 40c | 70.00 |
| Concrete steel floor in engine room and roof over coal bins | 1176.00 |
| Brick floor in boiler room and coal bin | 325.00 |
| Lumber | 1020.40 |
| Slate roof | 650.00 |
| Tinner's work | 130.00 |
| Windows and doors | 409.00 |
| Stairs and steps | 100.00 |
| Hardware | 74.00 |
| Iron work not otherwise covered | 22.65 |
| Painting | 150.00 |
| Ash elevator and motor | 550.00 |
| Carpenters' work | 400.00 |
| Profit 15% | 1294.77 |
| | <hr/> |
| | \$10,476.57 |

CHIMNEY.

| | |
|-------------------------------------|----------|
| 125 yds. excavation | \$ 37.50 |
| 65 yds. concrete foundations..... | 390.00 |
| 160 M common brick laid..... | 2240.00 |
| 10 1/2 M fire brick laid..... | 315.00 |
| 165 cu. ft. cut stone..... | 288.75 |
| Iron work and lightning conductor . | 162.00 |
| Boiler breeching . | 445.00 |
| Profit 15% | 440.00 |

\$3818.25

Total for building and chimney.....\$14,294.82

Deduction for changes in roof construction
and stone noted above (estimated).....1156.82

Engineers' final estimate.....\$13,138.00

It is interesting to note that the contract for the building and chimney was let at the above estimate. It may be further noted that the building contractor constructed the machinery foundations, the specifications requiring him to name a price per yard of finished foundation. The price named was \$6.00 per yard. In all foundations there were about 210 yards, so the cost was \$1265.49 for this work.

THE ENGINES AND GENERATORS.

The plant is equipped with two 12" x 22" x 30" tandem compound Corliss engines (Fig. 5,) built by the Murray Iron

Works Co., each direct connected to standard 125 k. w. generators, running at 120 r. p. m. These engines have the rolling mill type of frame, which is of particularly massive and pleasing design, and double valve gears giving a range of cutoff from 0 to $3/4$ stroke, thus making possible a very large over-load capacity. The point of cut-off in the low pressure cylinder is controlled by hand, a particularly ingenious arrangement being provided to change the cut-off while the engine is running. The cylinder ratio is such as to permit, later, of the use of condensing apparatus, should the conditions of operation of the plant warrant its use.

THE BOILERS.

There are three Murray water tube boilers set in one battery (Fig. 6.) Each boiler has about 1800 sq. ft. of heating surface. The design of the boilers is similar to that of the well known Heine boiler, except that the main shell is horizontal, the rear

Fig. 6.

header being longer than the front one. The arrangement of the baffle tile is exactly the same as in the Heine boiler. The boilers are designed for a working pressure of 150 lbs. Two of the boilers are in use at night to carry the lighting and pumping load, while during the day, one boiler only is needed. The third unit is for reserve, thus giving ample time for cleaning and repairs.

AUXILIARY STEAM APPARATUS AND PIPING.

(Fig. 7)

The feed water for the boilers is taken from the City mains through a float valve into a Hoppe's open exhaust steam heater of the induction chamber type, in which only a sufficient amount



Fig. 7.

of steam to heat the water is taken into the heater. The heater is provided with an efficient oil separator, which effectively prevents the introduction of oil into the feed water. A pair of

6" x 4" x 6" duplex boiler feed pumps are installed. The feed water is taken from the heater, or through a by-pass from the City mains, and pumped into a header from which it is delivered into the boilers through suitable controlling valves, located immediately above the pumps. All feed pipe and fittings are extra heavy and flanged; the pipe is bent at turns, thus doing away with the use of elbows.

The steam header is supported on brackets on the boiler room side of the wall between the engine and boiler rooms. It is 10" diameter, and is made up of extra heavy flanged fittings and full weight standard pipe, with screwed extra heavy companion flanges and copper gaskets. The 7" connections from boilers to header are made of long bends, and are provided with extra heavy flanged, rising stem gate valves with by-passes. Long radius bends connect the header and the engines, a milwaukee separator being placed above each engine. A 4" steam pipe from the header, leads to the old pipe across the street from the new plant. As this is only a temporary installation the pipe was carried in a wood box, filled with mineral wool. The bleeds from the header and from the separators are taken care of by traps and delivered into the heater.

The exhaust pipe is 10" and 12" in diameter. Either engine can be cut out by a standard rising stem gate valve. Long radius ells are used throughout. After leaving the heater, the exhaust passes through a back pressure valve, from which steam may be delivered to the heating coils in the engine room. A cross connection with the steam header is made with this low pressure supply pipe, with a pressure reducing valve between, to enable the engine room to be heated in cold weather when the engines are not running. The condensation from these heating coils is returned into the heater.

The blow-off pipe is made of extra heavy flanged pipe and fittings in the boiler room and of standard cast iron water pipe between the building and the grease trap. A 4" waste pipe takes the overflow from the heater, the discharge from the engine receiver traps, etc., to this same grease trap, and a 6" sewer pipe delivers the water from the trap. Extra heavy "Neverstick" blow-off cocks are used on the boilers, and in addition a gate valve is placed in tandem with each blow-off cock.

All pipe work above two inches in diameter is flanged, and made up with corrugated copper gaskets. On all high pressure lines, extra heavy fittings and valves are used. The pipes are covered with Johns-Manville 85% magnesia sectional covering.

The engineers' estimate of the cost of pipe work was as follows:

| | |
|---|-----------|
| Exhaust connections, complete,..... | \$900.00 |
| Steam Header, complete,..... | 750.00 |
| Feed water and pump connections,..... | 160.00 |
| Blow-off and waste connections,..... | 160.00 |
| Steam heating connections,..... | 114.00 |
| Drips and gaskets,..... | 60.00 |
| Pipe line to old pump house and other outside work | 300.00 |
| Pipe covering..... | 100.00 |
| Labor | 500.00 |
| Profit, 15% | 456.00 |
| | <hr/> |
| | \$3500.00 |

The contract for the pipe work was let for \$3270.00,

ELECTRIC GENERATORS.

The generators, Fig. 8 were made by the Bulloc Electric Manufacturing Company. They are of the revolving field, engine type and have a capacity of 125 kilowatts each. These machines are sixty cycle, three phase, star connected, giving a

Fig. 8.

pressure of 4,400 volts between circuits. The regulation is a rise of 8 per cent in pressure when normal, full noninductive load is thrown off, and a rise of 18 per cent when load has 80 per cent power factor. The generators are each furnished with a belted exciter rated at 104 amperes and 120 volts.

LIGHTING SYSTEM AND SWITCH BOARD.

The streets are lighted with 328.7 1/2 ampere, series alternating arc lamps hung over street intersections. These lamps are arranged, (Fig. 17,) in six nominally fifty light and two twenty five light circuits, each circuit being controlled by an induction regulator. The switch board complete, lamps and regulators were furnished by the Western Electric Company. Under ordinary running conditions each fifty light circuit is attached directly, through its regulator, to one of the six phases of the two generators, the machines being run independently of each other. A fifty light transformer is, however, so arranged that any one of the six circuits can be isolated by the action of plug switches, from the generator in case of an outside ground coming on. The two twenty five light circuits are of course fed through transformers at all times. There is also one incandescent circuit taking from 1.2 to 1.45 amperes direct from the machine at 4,400 volts. The circuits above enumerated constitute the present load, but provision has been made for a future motor load in connection with city water supply.

. (Illustration Fig. 17, on Page 29.)

I

Fig. 17.

II

(Fig. 9) shows diagrammatically the wiring of station and lighting circuits. The several series circuits are, in the diagram, shown open at several points on the switch board. These are

**DIAGRAM OF
SWITCH BOARD AND LIGHTING CIRCUITS**

**RICHARDS AND MORSE
CONSULTING ENGINEERS**



Fig. 9.

merely spring contacts, held apart by wooden plugs, for testing purposes, the plugs being removed and springs allowed to come together when the circuit is to be placed in operation.

The switch board, (Fig. 10,) comprises, four arc panels with plug switches, each panel supplying two circuits and being provided with one ammeter which may be inserted in either circuit at pleasure, without interrupting the service; one incandescent panel; which is also provided with three plug switches so

Fig. 10.

arranged that a station test circuit (Not shown,) may be cut into, or out of, one of the twenty five light circuits without interrupting the latter; two generator panels and one induction motor panel, the last named not being as yet in use, nor accounted for among the items of cost in this article.

POLE LINE AND WIRING.

This was constructed under contract by the Nebraska Electric Company of Omaha.

All poles of thirty five feet and over are of Idaho Red Cedar of excellent quality; thirty foot poles and guy stubs are of Michigan White Cedar. The cost of poles to the contractor as received F. O. B. Lincoln was as follows:

| | | | |
|----|-----|----------------------|--------|
| 8" | 50' | Red Cedar Poles..... | \$9.00 |
| 8" | 45' | " " " | 8.00 |
| 7" | 40' | " " " | 4.75 |
| 6" | 35' | " " " | 3.60 |
| 6" | 30' | White " " | 2.50 |
| 6" | 25' | " " " | 1.90 |
| 5" | 20' | " " " | 1.10 |

The number of each size employed in the construction of the lines as laid out on the map, Fig. 17 were,

| | |
|---------|----------|
| 2-60' | 1438-35' |
| 4-55' | 440-30' |
| 55-50' | 168-25' |
| 105-45' | 150-20' |
| 291-40' | 90-18' |

The poles at all corners, turns and ends, were double armed and these

Fig. 11.

branched guys consisted, in the trunk, of three strands of No. 8

Fig. 12

galvanized iron wire, two strands being used in the branches. All lamp sustaining poles were guyed in two directions, using for the purpose, two strands in each guy.

Fig. 13.

An analysis of the actual cost of the various materials and operations involved in the construction of the line including contractors profits equally distributed is as follows. All wires were of hard drawn copper No. 8 B and S gauge, there being a total of 105 miles of wire strung.

MATERIALS.

| | |
|---|-------------|
| Poles..... | \$10,908.80 |
| Cross arms, pins, insulators, hardware, guy wire, lamp sustainers, ropes and pulleys.... | 4,322.04 |
| Copper wire..... | 8,511.62 |
| | <hr/> |
| | 23,742 46. |

LABOR.

| | |
|--|------------|
| Shaving poles..... | \$1,058.58 |
| Framing and roofing poles..... | 394.55 |
| Hauling poles..... | 176.56 |
| Distributing poles..... | 520.02 |
| Digging holes | 1,693.14 |
| Setting poles..... | 1,352.46 |
| Arming poles..... | 404.34 |
| Painting pole tops..... | 70.96 |
| Guying poles..... | 2,161.43 |
| Stringing wires..... | 2,021.99 |
| Putting up lamp sustainers..... | 611.75 |
| Placing globes and hoisting ropes..... | 1,114.75 |
| | <hr/> |
| | 11,580.53 |

MISCELLANEOUS EXPENSES.

| | |
|--|------------------------|
| Incidental expenses of Superintendent..... | \$431.82 |
| Livery and incidental hauling..... | 180.00 |
| Rent of warehouse..... | 105.00 |
| Miscellaneous freight | 90.96 |
| Tools..... | 128.15 |
| Fire insurance and bond..... | 199.56 |
| | <hr/> |
| | 1,135.49 |
| Total cost of pole line and wiring..... | \$36,458.48 |
| The average cost of labor during construction was: | |
| General foreman, per day, 9 hours and expenses..... | \$3.50 per day. |
| Sub-foreman of guying gang, and string- ing gang..... | 3.20 per day. |
| Foreman of pole yard and digging gang | 3.00 per day. |
| Lineman..... | 2.75 per day. |
| Ground-men..... | 2.00 and 1.75 per day. |
| Laborers, digging holes and in pole yard | 1.75 per day. |

Figs. 14 and 15 illustrate the manner in which labor was applied in the process of erecting poles and tamping in the dirt respectively.

Fig. 14.

Fig. 14.

Fig. 15.

Fig. 16 shows the wires as they enter the power house.

Fig. 16.

COST OF PLANT.

| | |
|---|-------------|
| Building, chimney and machinery foundations | \$14,403.49 |
| Boiler feed pumps..... | 396.00 |
| Feed water heaters..... | 360.00 |
| Incandescent lighting transformers..... | 194.25 |
| Engines and boilers..... | 12,200.00 |
| Generators and exciters..... | 7,490.00 |
| Switchboards, regulators and lamps..... | 8,030.00 |
| Steam fitting..... | 3,283.00 |
| Pole line and wiring..... | 36,458.48 |
| Engineering design and supervision..... | 3,312.62 |
| | <hr/> |
| | \$86,128.04 |

The plant is located in a public park on the outskirts of the city, hence no charge is made for real estate. Since the plant was completed and put in operation, \$1,174.93 has been expended for additional equipment. This consists of testing instruments, special tools, furniture, etc., much of which is non-essential to actual operation.

1,174.93

Total cost of plant 87,302.97

COST OF OPERATION

The following items are taken from a report on the first six months of operation, ending February 28, 1906. Each item has been doubled as the estimate is based on yearly operation.

(ANNUAL EXPENDITURE BY THE CITY.)

| | |
|--|------------|
| Interest on bonds; 4 1/2% of \$65,000..... | \$2,925.00 |
| Coal; 2330 tons at \$2.35 per ton..... | 5,475.50 |
| Oil and waste..... | 250.00 |
| Packing..... | 68.00 |
| Miscellaneous..... | 50.00 |
| Carbons..... | 321.12 |
| Arc globes..... | 198.68 |
| Office supplies..... | 14.00 |
| Pay roll; supervision and labor..... | 7,511.46 |
| | <hr/> |

\$16,813.76

The equivalent number of lamp hours supplied is 880,908

Hours run annually per lamp 2,677

Killowatt hours generated per annum 488,870

(The last figure is estimated on basis of 550 watts per arc lamp including line loss. Lamps were guaranteed to absorb not less than 480, nor more than 490 watts. The energy required by the very small incandescent load is also included.)

In order to obtain the annual cost to the city, of owning and operating its own lighting plant, taking into account all financial features involved, the following estimate has been made. This estimate is based, as far as possible, upon the figures above given reduced to a yearly operation of 4,000 hours per lamp.

Annual Cost to the City, All Financial Features Considered.

| | |
|--|-------------|
| Interest on bonds, 4½ per cent. of \$65,000..... | \$2,925.00 |
| Interest on cash cost (\$87,302.97) of plant, less \$65,000 at 5 per cent. | 1,115.15 |
| Depreciation and repairs at 10 per cent..... | 8,730.30 |
| Coal | 8,175.60 |
| Oil and waste | 275.00 |
| Packing | 78.00 |
| Miscellaneous | 50.00 |
| Carbons | 481.12 |
| Arc globes | 218.68 |
| Office supplies | 14.00 |
| Water at 15c per 1,000 gallons (Same rate as charged all steam users in city)..... | 750.00 |
| Pay roll | 7,511.46 |
| Taxes at 7½ mills per \$1.00 | 654.77 |
| Fire insurance at 2 per cent. on \$32,000..... | 640.00 |
| Boiler insurance | 200.00 |
| Franchise tax; \$100 per annum plus 2 per cent on estimated gross income of a private plant | 700.00 |
| Total | \$32,519.08 |

The taxes which figure in the above, are those that the City would receive from a private company doing the public lighting, and which are therefore lost through the City's operation.

The figure just found is for 329 arc lamps operating all night, every night, and also includes the small quantity of incandescent lighting. The effect of this latter load is negligible. We therefore have as the total cost per arc lamp per annum, \$98.84.

Recent Practice in the Construction of Bridge Piers on Pile Foundations.

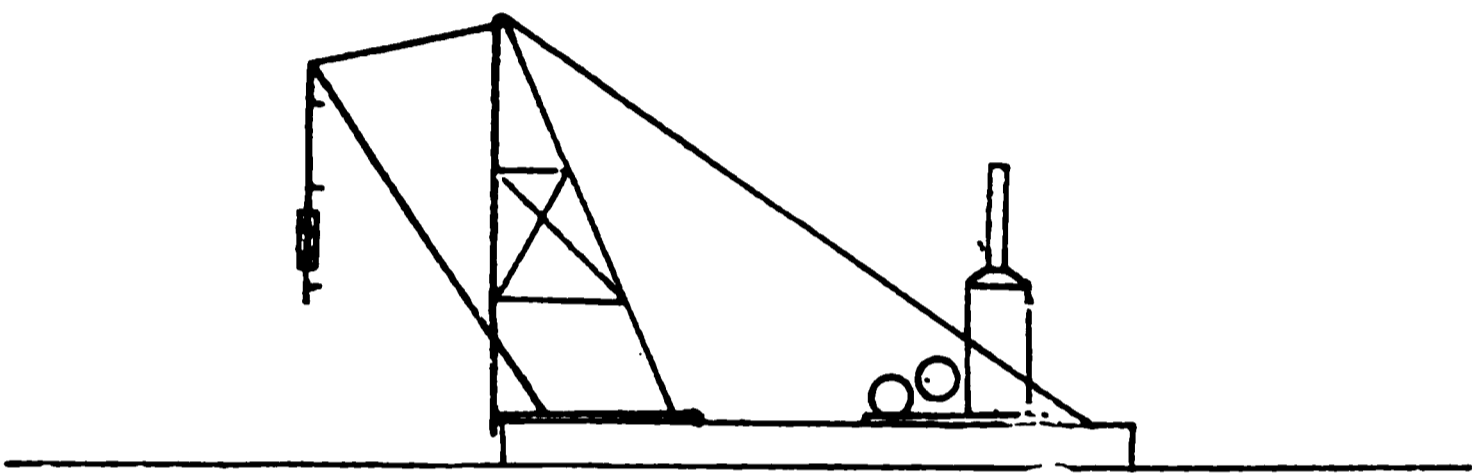
W. M. Kallasch, Assistant Engineer, Bridge Department, Illinois Central Railway.

The substructure of Yazoo River Bridge was finished in 1904. It consists of a concrete abutment, three double steel cylinder concrete piers, and a circular pivot pier, which supports a 239 foot single track draw span. All of these piers rest on pile foundations. In the case of the cylinders, clusters of piles were driven with a floating driver. The tops of the piles were then chained together, and the bottom sections of cylinders placed over them, correctly centered, and driven to their proper depth into the bed of the river. The bottoms of cylinders were closed by depositing a layer of concrete through the water by means of a tube consisting of a six-inch iron pipe, and when concrete had set, the water was taken out with a steam siphon. The piles were cut off at low water and the cylinders filled with concrete. For the foundation of the pivot pier, 130 piles were driven to a total penetration on each pile of from 16 to 24 ft., and to a penetration of from 2 inches to absolute refusal under the last blow of a 3000-lb. hammer falling 30 feet. It was decided to build a double wall coffer dam, and fill between with puddle.

The coffer dam was made octagonal in shape, except that two of the alternate up-stream sides were produced to a point to deflect the current. This was also used as a sump hole for the pump. Frame piles for the walls were spaced 4 feet for inside wall, and 5 feet for outside wall. They were driven with the same driver used in driving foundation piles. The distance, center to center, of inside and outside walls, was 8 ft., making the puddle wall 5 ft. thick.

Sheet piles were built out of 3x12 rough lumber, and were two-ply, 40 ft. long. They were driven with a 3000-lb. hammer in a pair of short pony leads. The leads were suspended from a boom hinged at the base of the leads on the barge driver.

This boom could be raised or lowered for driving either the outside or inside wall of the coffer dam, with the barge anchored against the wall.



Sheet piles in both walls were given a penetration of about 14 ft., the intention being to drive through a bed of quick-sand underlying the pier site, but through which it was not intended to excavate. The puddle for the wall was a sticky, yellow clay, taken from the bank of the river near by, and was dumped into the water and rammed down. A double cylinder steam pump with an 8-inch suction and a 6-inch discharge was used for handling the water. Excavated material was handled in buckets with a derrick mounted on top of the coffer dam. Excavation was carried down to near the right depth and foundation piles cut off. At this time there was a head of about 20 ft. of water on the outside of the dam, and an enormous spring broke through the bottom of the foundation. So great was the flow of water and sand that the facilities for handling it were entirely inadequate, and the dam was fast filling up with sand. A hole was cut through the wall so as to fill the dam with water and equalize the pressure, and a 10-inch centrifugal pump was then installed. By keeping the dam full of water, the sand was pumped out to the proper depth.

A diver was employed most of the time to direct the moving of the suction hose, so as to excavate the bottom to a uniform depth. The bottom of the dam was then closed by depositing a 2-ft. layer of concrete through the water, by means of bottom dump-buckets, which were lowered to the bottom before being dumped. The wall of the coffer dam was repaired, and as soon as the concrete had set, the water was pumped out without further difficulty. The remainder of the foundation and the pier were put in, in the usual manner. The frames of the pier were built in short, vertical sections fitting smoothly into each other, so that the lower ones could be unbolted, removed, and placed on top. Upon the completion of the work the inside row of sheeting was cut off at the top of the foundation, and the outside row was pulled up. The work of constructing the piers, and erecting the steel, was done by company forces.

The substructure of the Tennessee River Bridge, which was completed early in 1905, consists of eight double-track concrete piers. Seven of these piers are for fixed spans, and the other one is a pivot pier which supports a 453-ft. double-track draw span. All of the piers are on pile foundations. The method of constructing the River piers was essentially the same.

The river bed is composed of clean sand and gravel, and in low water the river is about five feet deep. Orange peel dredges were used to excavate the pier sites to about 17 ft below low water. The foundation piles were then driven with a steam hammer

mounted on a barge. On account of the nature of the bottom, it was necessary to use cast iron points on all foundation piles.

In general, they were driven to refusal, or as much as they would stand, the total penetration on each pile varying from 7 to 20 feet.

The coffer dams were all single wall dams. The sheeting used was the Wakefield pattern, and was built up of a 4x12 tongue piece and 3x12 sides, and were 36 ft. long. The frame for the coffer dams consisted of a row of piles driven about 4 ft. center to center around the foundation, with three 12x12 wales bolted on the outside. These were placed 6 ft. center to center, vertically, over each other.

Sheet piles were driven with a 3000-lb. hammer running

in short, pony leads blocked cut in front of the leads on an ordinary barge pile driver.

The coffer dams for all piers, except the pivot pier, were rectangular, and were braced across the inside.

In the case of the pivot pier, the foundation which rests on 370 piles is octagonal in shape, and the coffer dam was made to conform to it, except that two of the alternate down-stream sides were extended to form a right angle, and the additional area

thus obtained was used to form a sump hole. It was originally intended to have this point up stream, but in order to better protect the pumping plant from boats, rafts and drift, it was placed down stream, so that the pump barge could be anchored below the coffer dam.

The foundation piles for the pivot piers were driven first in the open water. The first piles were accurately located by two transits on two different base lines, and a third on a line parallel to center of track as a check on the other two. As soon as several rows of piles were driven, a submerged circular saw was started, cutting them off below low water. This saw was fixed

on the end of a vertical shaft, the bearings of the shaft being bolted to a heavy vertical timber which could be raised or lowered in the leads of a pile driver mounted on a barge.

The frame piles for the coffer dam were next located by the same method as the first foundation piles. Outside wales for the octagonal dam were the same as for the rectangular dams. The

inside bracing consisted of a 12x14 wale bolted to the inside of piles just above the water. The sides and corners of the dam were trussed and bolted, as shown in plan, so as to form a circular arch-like resistance to the pressure on the outside.

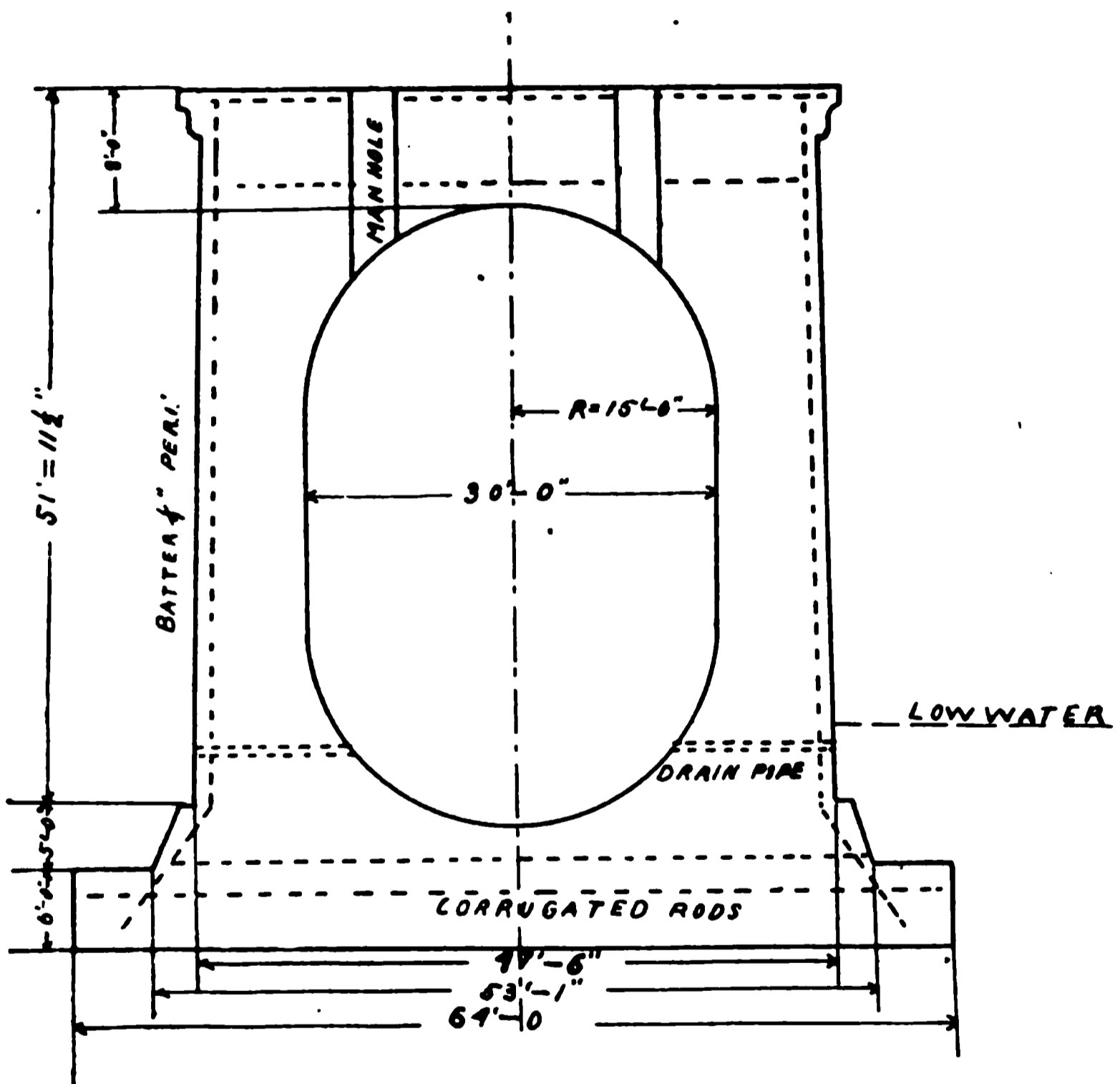


SECTION AA

*GENERAL PLAN
COFFER DAM FOR PIVOT PIER
YAZOO RIVER BRIDGE*

All material, both for sheet piles and waling was Southern Long Leaf Yellow Pine. The outside of the dam was banked with soft mud about half way up to the water line.

The first three feet of concrete in the foundation was composed of one part cement, two of sand and three of stone. It was lowered through the water by means of bottom-dump buckets. The water was then pumped out with a single 10-inch centrifugal pump, there being no leak of any consequence. The shaft

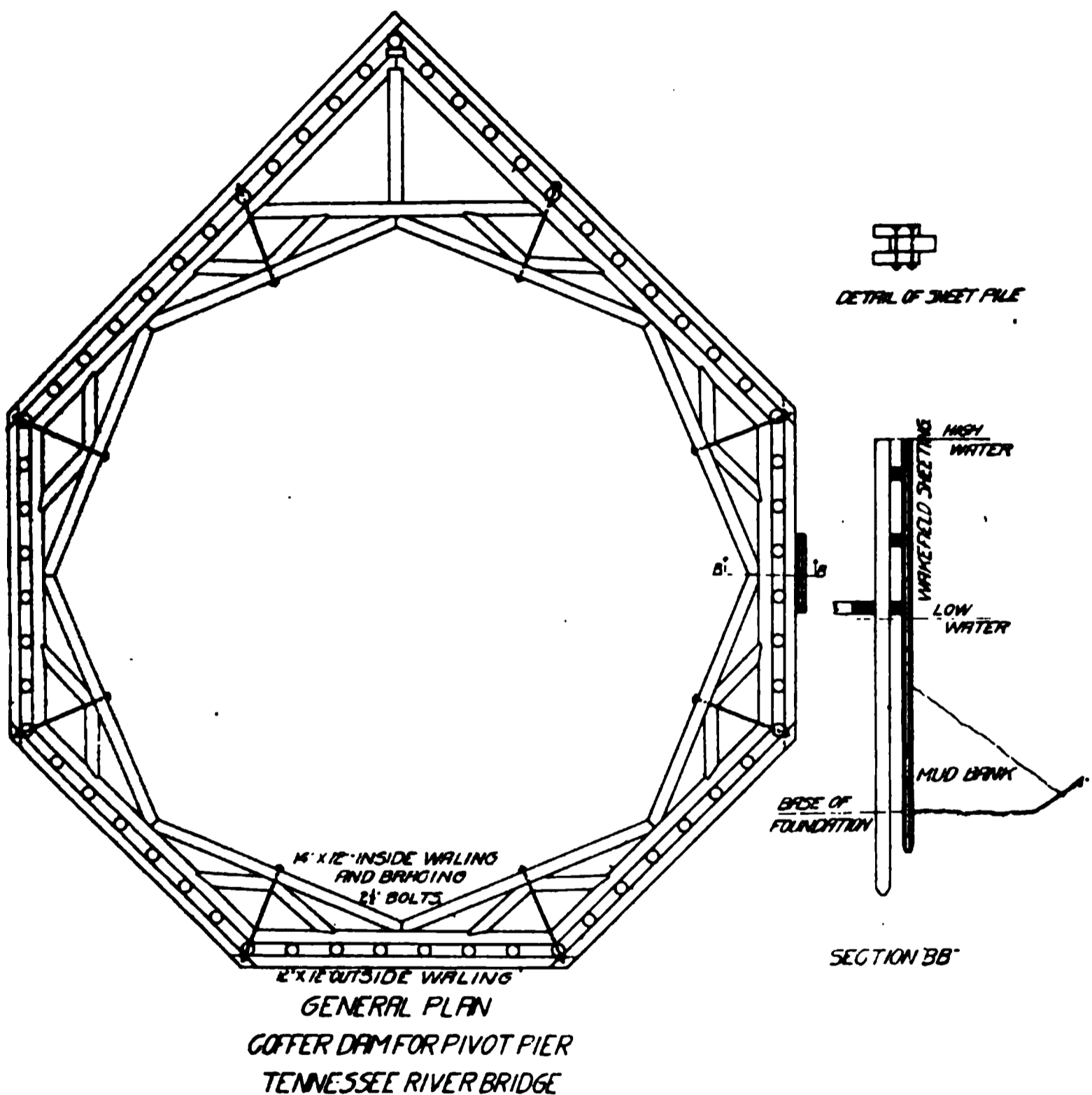


of the pivot pier is circular, sides batter one-fourth of an inch in one foot. At the base it is 47 ft. 6 in. in diameter. The inside is a hollow cylinder 30 ft. in diameter, with a dome top and inverted dome at the bottom.

Four drain pipes are placed below low water line so as to allow the water to pass in and out of the pier as the river stage

varies. The frames for the pier were all built on shore in sections, and afterward taken to the pier site and put in place with a derrick.

Eighteen thousand linear feet of three-quarters of an inch corrugated bars were used in re-enforcing the concrete. A network of bars spaced two feet center to center were located in the foundation, another in the footing, another just above the



dome, and another in the top of the coping. Bars were also placed two feet apart, both horizontally and vertically, six inches from the outside face of the pier.

The mixing plants used on the river piers consisted of Smith mixers mounted on barges, with a stiff-leg derrick on one end of the barge to handle the material from the supply barges to the mixer, and one on the other end to handle the concrete from the mixer to the forms. Material was transferred from the shore to the mixing plant by means of a steam boat and supply barges.

Upon the completion of the work the coffer dams for the inner piers were all pulled.

At several places in the Mississippi Valley double track concrete piers are being built at the present time. They are all of the I. C. standard design, having pointed ends formed by the intersection of two circles. Faces are battered one-half an inch in one foot, and the ends of the noses are battered to conform to the sides. All piers now being built are on pile foundations, the piles intended to take the entire loading.

At Wickliffe, Kentucky, where two piers are being constructed, the underlying material is a very tenacious light-colored clay, locally known as "rubber clay." On being worked or handled, it becomes very soft and sticky, and is impervious to water. The sheeting used in this material is a single row of tongued and grooved 3x12, which are 20 feet long, and is found to be so satisfactory that it will be extensively used on work of a similar nature. The coffer dams are 62x21 ft. and 18 ft. deep. The frames consist of three rows of 8x10 wales, placed one above the other.

For driving the sheeting, a driver was constructed very similar to the one shown on page 48, Fowler's "Ordinary Foundations," except that the hammer weighs about 600 lbs., and in the absence of suitable steam power, a more or less economical Southern combination, a negro and a team of mules, were used to operate the hammer. In general, pile foundations are designed so that the loading on each pile does not exceed 15 tons, where piles are to take the entire load. The tops of the piles are cut off below the low water line. Piles are driven so that the sustaining power, computed by the familiar formula $\frac{2wh}{s+1}$ is about 30 tons.

Concrete in foundations supported by piles is re-enforced by network of corrugated bars spaced 2 ft. center to center, both ways. Concrete foundations and pier shafts is generally composed of one part standard Portland cement to three parts of clean, sharp sand, and six parts of stone.

Copings are composed of 1-2-4 concrete, and re-enforced with corrugated bars. A facing of mortar, composed of one part

cement and two parts of sand, is used on all exposed concrete surfaces.

In general, concrete is mixed and placed so wet that a great deal of tamping is not required.

Machine mixers are required wherever warranted by the importance and size of the work.

Gas Engine Economy.

L. A. Sheldon, L. W. Turner, D. L. Mills.

These tests were made in the spring of 1905 by L. W. Turner, L. A. Sheldon and D. L. Mills for the purpose of determining the conditions of best efficiency.

The method adopted was to run a series of tests varying one condition and keeping the rest constant. Four such series were run. The variables being temperature of jacket, water, mixture of gas and air, point of ignition in degrees back of dead center, and compression.

All of the measuring instruments were carefully calibrated so that the results are as accurate as possible, and it is safe to assume that they are correct within three per cent.

The engine used was built by the Springfield Gas Engine Co., of Springfield, Ohio, U. S. A. It is rated at 8 B. H. P. at a speed of 260 R. P. M., occupies a floor space of 72" by 42" and weighs 2400 pounds. It is of the ordinary horizontal type, having a cylinder of 7" diameter and 12" stroke, water jacketed from end to end with the head cored out for cooling. The piston is of the trunk type with four compression rings turned concentric with the cylinder. The inlet and outlet valves are mounted on removable castings. The preliminary exhaust consists of a port or opening cut in the side of the cylinder which is uncovered by the piston just before it reaches the outer end of the stroke; thus the exhaust valve, which is opened by a cam, has only to open against a slight back pressure and release the burnt gas remaining, displaced by the piston after the preliminary port is closed.

The heat given up to the jacket water was determined by taking the weight of water passing through and the temperature before and after going through the jacket. The water was taken from the city mains, and on account of its variable pressure, it was difficult to keep the temperature constant.

The exhaust from the engine was so arranged that a part was passed into a chamber built of common brick laid without mortar. The amount of gas entering was just enough to produce atmospheric pressure in the chamber. The temperature was taken at this pressure. From this the heat rejected to exhaust was calculated. The gas used was measured by means of a Westinghouse No. 1 wet gas meter. A gas bag was placed between the engine and meter to take care of the fluctuations in pressure. The pressure and temperature of the gas taken as it left the meter.

The air used was supplied by a small Buffalo fan blower which passed the air through a meter (Westinghouse No. 3) so that the air used could be accurately measured. Between the blower and the meter a safety valve was placed so that any desired pressure could be maintained. The temperature was taken near the blower.

The indicated horsepower was found from cards taken with Tabor outside spring indicators. The reducing motion was of the pendulum type.

The brake used was built from the plans given by E. C. Oliver, in Vol. XXIV of the American Society of Mechanical Engineers.

A cast iron water cooled brake wheel 16" in diameter was used to brake on. The brake shoes were of soft wood (poplar) backed by a 2" piece of maple, $\frac{1}{2}$ " thick, alternating strips forming the bearing surface. The strips were slightly inclined across the face of the shoe, the object being to insure smooth and even lubrication. This brake gave excellent satisfaction, as it was easy to regulate and would keep a constant load with very little attention.

Ignition was accomplished by an Apple Ignition Dynamo, built by the Dayton Electrical Co., of Dayton, Ohio. The dynamo charges a storage battery while running and the static charge is used in starting the engine. When it is up to speed the battery is cut out and the charges ignited from the dynamo. The time of ignition is governed by hand, the apparatus consists of a disc graduated to degrees, on the cam shaft. The zero of readings corresponding to the inner dead center while at rest.

The point of ignition is varied by moving an arm carrying a copper brush which makes contact with another strip on a rubber disc.

The compression was varied by making the connecting rod of a length such that the largest clearance was about 60 per cent. and the smallest clearance about 25 per cent.

On account of the valves the piston could not be made to extend any farther back in the cylinder so a hollow cast iron plug was screwed into the back end of the piston to reduce the clearance. On account of the preliminary exhaust port a guard was made and put on the end of the piston so as to make it uncover the preliminary exhaust port at the proper time.

The first test was run with the largest clearance possible and for each following test a liner was added to the length of the connecting rod and a corresponding amount cut off the guard controlling the preliminary exhaust port.

The clearance was measured after each test by filling the clearance space with water and correcting for temperature. The speed of the engine was kept constant during each test by means of an inertia governor. The R. P. M. were taken by means of a continuous counter attached to the secondary shaft. The number of admissions were recorded by a continuous counter attached to the intake valve. The gas was tested, after each day of testing, with a Junkers Gas Calorimeter. The calorific value in B. T. U.'s per cubic foot was corrected to correspond to a temperature of 60° F. and a pressure of 14.7 pounds.

Explanation of data given in reports:

1. The length of the tests was thirty minutes. Indicator cards and temperature readings were taken every five minutes. Amount of gas and air, total revolutions, total explosions and weight of jacket water was taken every fifteen minutes.

2—24. Explained before.

25. The ratio of air to gas is the ratio between these volumes standardized at 60° F. and 14.7 pounds pressure.

26. The volume of "N" in the equation, $PV^n=C$, was obtained on most of the cards from the maximum pressure and the pressure at release, with the corresponding volumes. Where the maximum pressure did not come at the beginning of the

stroke, as in the ignition tests, the pressure was taken late enough on the card to be certain that it was on the expansion line.

27—33. The pressures given are the averages of all the cards from a test.

The cards were taken with two Tabor outside spring indicators, one with a forty pound spring and stop for the suction and back pressure lines, and the other with a two hundred pound spring. The mean effective pressures were obtained from the cards by the use of an Amsler Polar Planimeter.

The mean effective back pressure was obtained from the lower loop of the low pressure cards. The difference of the two gives the net mean effective pressure.

34—37. The temperature of the exhaust at atmospheric pressure was taken with a thermometer inserted in the exhaust chamber. The temperature at release, compression and maximum explosion were calculated from the pressure at the corresponding points as explained in Hutton's "Gas Engines."

38—40. The brake work in foot pounds was determined by the use of a pony brake. The length of the brake arm was 39.39 inches and a constant load of 30 pounds was kept on the scales.

42—44. The indicated horse power was calculated from the net mean effective pressure.

41—43. The B. T. U. equivalents were obtained by dividing the foot pounds of brake work per hour by 778, and by multiplying the indicated horse power by 254.5.

45. The mechanical efficiency is the ratio of B. H. P. to I. H. P.

46—47. The thermal efficiencies for the I. H. P. and B. H. P. is the ratio between the heat equivalent of the work done and the total heat available.

48—51. The fuel consumption per brake and indicated horse power hour was calculated from the amount of gas used as given by the meter. The cost of power was calculated on the assumption that gas cost \$1.20 per thousand cu. ft.

52. Explained before.

54. The heat available was calculated from the amount of gas used per hour at standard temperature and pressure.

55. The heat used to produce maximum pressure was obtained from the temperatures at maximum explosion and compression, the amount of air, gas and neutrals in the cylinder per stroke, the number of explosions and $C_v = .1691$. Method explained in Hutton's "Gas Engines."

56. The per cent of heat suppression is the difference between 54 and 55 divided by 54.

57. The heat turned into work is the B. T. U. equivalent of the I. H. P.

58. The heat rejected to jacket water is obtained from the range in temperature and weight of jacket water.

59. The heat rejected to exhaust is calculated from the temperature at exhaust and the temperature of the charge after it is drawn into the cylinder. This value is given as H_2 in Hutton's "Gas Engines."

60. The heat lost by radiation and conduction is the heat available less the heat turned into work, rejected to jacket water and rejected to exhaust. This would include any after burning effect and any leakage or other loss.

61. The value of R was calculated from the formula $\frac{PV}{T} = R$ using atmospheric pressure as 2117 pounds per square foot, the volume of cylinder and clearance in cu. ft. and the absolute temperature of the mixture of air, gas and neutrals.

62. Explained before.

Report of Tests with Variable Jacket Water Temperature.

GAS ENGINE ECONOMY.

VARIABLE JACKET WATER.

| | A | B | C | D | E |
|---|--------|-------|-------|-------|-------|
| Barometer | 14.13 | 14.12 | 14.12 | 14.12 | 14.12 |
| 1. Time Intervals | 5. | 5. | 5. | 5. | 5. |
| Revolutions and Explosions | | | | | |
| 2. Total Revolutions | 7826.1 | 7470. | 7740. | 7748. | 7668. |
| 3. Revolutions Per Minute | 260.9 | 249. | 258. | 258.2 | 255.6 |
| 4. Total Actual Explosions | 2971. | 2986. | 2955. | 2890. | 2980. |
| 5. Actual Explosions Per Minute | 99. | 99.5 | 98.5 | 96.3 | 99.8 |
| 6. Ratio of Revolutions to Explosions | 2.64 | 2.5 | 2.62 | 2.68 | 2.58 |
| 7. Explosions Missed Per Minute | 31.5 | 25. | 30.5 | 32.8 | 28.5 |

JACKET WATER.

| | | | | | |
|---|--------|--------|--------|--------|-------|
| 8. Total Weight | 285.5 | 200.5 | 164.5 | 140.5 | 24.5 |
| 9. Weight, Pounds Per Hour | 571. | 401. | 329. | 281. | 49. |
| 10. Initial Temperature | 64. | 64. | 65. | 65. | 74. |
| 11. Final Temperature | 135. | 163. | 180. | 192. | 210. |
| 12. Range of Temperature | 71. | 99. | 115. | 127. | 136. |
| 13. Heat Absorbed B. T. U. Per Hour | 40541. | 39699. | 37835. | 35687. | 6664. |

AIR.

| | | | | | |
|--|-------|-------|-------|-------|-------|
| 14. Cubic Feet From Meter | 581. | 602. | 635. | 520. | 625. |
| 15. Cubic Feet Per Hour | 1172. | 1204. | 1270. | 1040. | 1250. |
| 16. Temperature | 89.7 | 90. | 93. | 92. | 92. |
| 17. Pressure, Inches of Water | 2.1 | 2.3 | 2.4 | 2.6 | 2.2 |
| 18. Cubic Feet Standard 60 degrees Fht. and 14.7 lb. | 1070. | 1099. | 1155. | 946. | 1138. |

GAS.

| | | | | | |
|--|-------|-------|------|-------|-------|
| 19. Cubic Feet From Meter | 100.2 | 95.8 | 94.5 | 80.8 | 89.8 |
| 20. Cubic Feet Per Hour | 200.4 | 191.6 | 189. | 161.6 | 179.6 |
| 21. Valve Index Reading | 2. | 2. | 2. | 2. | 2. |
| 22. Temperature | 95.6 | 97. | 98. | 96. | 99. |
| 23. Pressure, Inches of Water | 2. | 2.06 | 2.6 | 2.3 | 1.9 |
| 24. Cu. Ft. Standard 60 degrees Fht. 14.7 lb. | 181. | 172.5 | 170. | 146. | 161. |

RATIOS.

| | | | | | |
|------------------------------------|------|------|------|------|------|
| 25. Of Air to Gas. | 5.9 | 6.36 | 6.78 | 6.48 | 7.06 |
| 26. Value of n in PVn equal C..... | 1.46 | 1.46 | 1.52 | 1.59 | 1.53 |

(Continued from page 59.)

VARIABLE JACKET WATER.

PRESSURES.

| | A | B | C | D | E |
|--|-------|-------|-------|-------|-------|
| 27. At End of Compression | 47.7 | 53.1 | 50. | 53.4 | 56. |
| 28. At Beginning of Expansion, Max. | 211.4 | 221.4 | 225.7 | 238.6 | 227. |
| 29. Mean Effective Back | 4.54 | 4.76 | 4.9 | 4.82 | 4.48 |
| 30. At End of Expansion | 36.8 | 38.6 | 36.6 | 35.7 | 36.6 |
| 31. Mean Effective | 63.6 | 68.55 | 65.64 | 66.51 | 64.26 |
| 32. If Expansion Carried to end of Stroke..... | 33.9 | 35.5 | 33.6 | 32.6 | 33.6 |
| 33. Net M. E. P. | 64.06 | 63.79 | 61.74 | 61.69 | 57.78 |

TEMPERATURE.

| | | | | | |
|--|-------|-------|-------|-------|-------|
| 34. Of Exhaust, Atmospheric Pressure | 283. | 222. | 213. | 212. | 210. |
| 35. At Release | 1003. | 971. | 951. | 919. | 948. |
| 36. At Compression | 103. | 150. | 113. | 157. | 182. |
| 37. Maximum Exploslon | 2096. | 2087. | -103. | 2300. | 2144. |

ENERGIES.

| | | | | | |
|--|---------|----------|----------|----------|----------|
| 38. Brake Work, Ft. Lbs. | 161558. | 154188. | 159761. | 161000. | 158275. |
| 39. Brake Work, Ft. Lbs. Per Hour | 9693500 | 9251292. | 9585678. | 9660000. | 9496512. |
| 40. Brake Horsepower. | 4.89 | 4.67 | 4.48 | 4.87 | 4.79 |
| 41. B. T. U. Equivalent to B. H. P. | 12459.5 | 11891. | 12321. | 12416.5 | 12206. |
| 42. Indicated Horsepower | 7.39 | 7.4 | 7.09 | 6.92 | 6.92 |
| 43. B. T. U. Equivalent to I. H. P. | 18817.7 | 18834.3 | 18044. | 17621.4 | 17631. |
| 44. I. H. P.—B. H. P. | 2.5 | 2.73 | 2.25 | 2.05 | 2.13 |

EFFICIENCIES IN PER CENT.

| | | | | | |
|-------------------------------|------|------|------|-------|-------|
| 45. Mechanical | 66. | 63. | 68.4 | 70.4 | 69.3 |
| 46. Thermal for B. H. P. | 11.8 | 11.8 | 12.4 | 13.05 | 13. |
| 47. Thermal for I. H. P. | 17.8 | 18.7 | 18.2 | 18.55 | 18.75 |

GAS.

| | | | | | |
|--------------------------------------|------|------|------|------|------|
| 48. Fuel per I. H. P. Per Hour. | -7.2 | 25.9 | 26.8 | 23.4 | 26. |
| 49. Fuel per B. H. P. Per Hour. | 41. | 41.2 | 39. | 33.2 | 37.5 |

COST OF POWER

| | | | | | |
|---------------------------------------|------|------|------|------|------|
| 50. Per I. H. P. Per Hour, Cents..... | 3.26 | 3.11 | 3.21 | 2.8 | 3.11 |
| 51. Per B. H. P. Per Hour, Cents..... | 4.92 | 4.93 | 4.68 | 3.98 | 4.5 |

VARIABLE JACKET WATER.

HEAT BALANCE.

| | | | | | |
|-----|--|---------|--------|--------|--------|
| 52. | Heat Value of Gas, Per Cubic Foot, Standard... | 583. | 583. | 583. | 583. |
| 53. | Point of Ignition | 19. | 19. | 19. | 19. |
| 54. | Heat Available From Test..... | 105523. | 99110. | 95118. | 93863. |
| 55. | Heat Used to Produce Max. Pressure..... | 39240. | 41580. | 38200. | 40580. |
| 56. | Per Cent. Heat Suppression..... | 62.8 | 58. | 60. | 57. |
| 57. | Heat Turned into Work From Diagram..... | 18817. | 18044. | 17621. | 17631. |
| 58. | Heat Rejected to Jacket Water..... | 40541. | 37835. | 35687. | 6604. |
| 59. | Heat Rejected to Exhaust..... | 16815. | 16960. | 13940. | 16900. |
| 60. | Heat Lost by Radiation and Conduction..... | 29350. | 26270. | 27870. | 52668. |
| 61. | R | 1.298 | 1.334 | 1.325 | 1.237 |
| 62. | Clearance, Per Cent. of Cylinder | 39.9 | 39.9 | 39.9 | 39.9 |

Report of Tests with Variable Mixture of Gas.

VARIABLE GAS MIXTURE.

Barometer 14.22
 1. Time Intervals 5.

REVOLUTIONS AND EXPLOSIONS.

2. Total Revolutions 7420.
 3. Revolutions Per Min. 247.3
 4. Total Actual Explosions 3301.
 5. Actual Explosions Per Min. 110.
 6. Ratio of Revolutions to Explosions 2.24
 7. Explosions Missed Per Min. 13.

JACKET WATER.

8. Total Weight 161.5
 9. Weight, Pounds Per Hour 323.
 10. Initial Temperature 70.
 11. Final Temperature 180.
 12. Range of Temperature 110.
 13. Heat Absorbed, B. T. U. Per Hour 35530.

AIR.

14. Cubic Feet From Meter 645.
 15. Cubic Feet Per Hour 1290.
 16. Temperature 82.
 17. Pressure, Inches of Water 2.2
 18. Cubic Feet at 60 degrees Fht., 14.7 lb. 1203.

GAS.

19. Cubic Feet From Meter 86.8
 20. Cubic Feet Per Hour 173.6
 21. Valve Index Reading 1.75
 22. Temperature 87.
 23. Pressure, Inches of Water 2.2
 24. Cubic Feet at 60 degrees Fht., and 14.7 lb. 160.4

RATIOS.

25. Of Air to Gas 7.5
 26. Value of n in PVn equal C 1.43

GAS ENGINE ECONOMY.

| | A | B | C | D | E |
|---|--------|--------|--------|--------|--------|
| Barometer | 14.22 | 14.22 | 14.22 | 14.21 | 14.19 |
| 1. Time Intervals | 5. | 5. | 5. | 5. | 5. |
| 2. Total Revolutions | 7420. | 7648. | 7786. | 8253. | 7998. |
| 3. Revolutions Per Min. | 247.3 | 254.9 | 259.5 | 266. | 266.6 |
| 4. Total Actual Explosions | 3301. | 3418. | 3103. | 3048. | 3137. |
| 5. Actual Explosions Per Min. | 110. | 113.9 | 103.4 | 98.3 | 104.6 |
| 6. Ratio of Revolutions to Explosions | 2.24 | 2.24 | 2.5 | 2.71 | 2.15 |
| 7. Explosions Missed Per Min. | 13. | 13.5 | 26.3 | 34.7 | 28.7 |
| 8. Total Weight | 161.5 | 136.5 | 184. | 165. | 150. |
| 9. Weight, Pounds Per Hour | 323. | 273. | 368. | 330. | 300. |
| 10. Initial Temperature | 70. | 66. | 64. | 63. | 63. |
| 11. Final Temperature | 180. | 178. | 184. | 184. | 188. |
| 12. Range of Temperature | 110. | 112. | 120. | 121. | 125. |
| 13. Heat Absorbed, B. T. U. Per Hour | 35530. | 30576. | 44160. | 39930. | 37500. |
| 14. Cubic Feet From Meter | 645. | 655. | 653. | 786. | 712. |
| 15. Cubic Feet Per Hour | 1290. | 1310. | 1306. | 1572. | 1424. |
| 16. Temperature | 82. | 84. | 86. | 90. | 93. |
| 17. Pressure, Inches of Water | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| 18. Cubic Feet at 60 degrees Fht., 14.7 lb. | 1203. | 1220. | 1210. | 1444. | 1300. |
| 19. Cubic Feet From Meter | 86.8 | 80.8 | 97.3 | 112.6 | 119.2 |
| 20. Cubic Feet Per Hour | 173.6 | 161.6 | 194.6 | 225.2 | 238.4 |
| 21. Valve Index Reading | 1.75 | 1.625 | 2. | 2.25 | 2.5 |
| 22. Temperature | 87. | 88. | 91. | 99. | 104. |
| 23. Pressure, Inches of Water | 2.2 | 2.1 | 2.2 | 2.1 | 1.5 |
| 24. Cubic Feet at 60 degrees Fht., and 14.7 lb. | 160.4 | 149. | 178.4 | 203.5 | 213.5 |
| 25. Of Air to Gas | 7.5 | 8.19 | 6.78 | 7.12 | 6.1 |
| 26. Value of n in PVn equal C | 1.43 | 1.34 | 1.47 | 1.48 | 1.42 |

(Continued from page 63.)

VARIABLE GAS MIXTURE.

| | A | B | C | D | E |
|--|-------|-------|-------|-------|-------|
| 27. At End of Compression | 55.1 | 62. | 54.9 | 56. | 55.3 |
| 28. At Beginning of Expansion, Max..... | 210.9 | 180.6 | 230.9 | 238.7 | 227. |
| 29. Mean Effective Back | 4.74 | 4.91 | 4.69 | 4.66 | 4.74 |
| 30. At End of Expansion | 38. | 41.4 | 39.7 | 40.7 | 41.7 |
| 31. Mean Effective | 61.17 | 55.6 | 65.47 | 69.45 | 64.83 |
| 32. If Expansion be Carried to End of Stroke | 35.1 | 38.4 | 36.50 | 37.4 | 38.5 |
| 33. Net M. E. P. | 56.43 | 53.69 | 60.78 | 64.79 | 69.09 |

TEMPERATURES.

| | | | | | |
|--|-------|-------|-------|-------|-------|
| 34. Of Exhaust, Atmospheric Pressure | 132. | 140. | 179. | 145. | 167. |
| 35. At Release | 929. | 1061. | 1022. | 1038. | 1110. |
| 36. At Compression | 140. | 218. | 154. | 157. | 165. |
| 37. Maximum Explosion | 1839. | 1519. | 2121. | 2173. | 2090. |

ENERGIES.

| | | | | | |
|--|----------|----------|----------|----------|----------|
| 38. Brake Work, Ft. lbs. | 153135. | 157864. | 160687. | 164715. | 165086. |
| 39. Brake Work, Ft. lbs. Per Hour | 9188130. | 9471882. | 9641232. | 9894912. | 9905160. |
| 40. Brake Horse Power | 4.64 | 4.78 | 4.87 | 4.99 | 5. |
| 41. B. T. U. equivalent to B. H. P..... | 11810. | 12175. | 12392. | 12718. | 12731. |
| 42. Indicated Horse Power | 7.46 | 7.03 | 7.33 | 7.42 | 7.33 |
| 43. B. T. U. equivalent to I. H. P. | 18980. | 17888.8 | 18650. | 18886. | 18650. |
| 44. I. H. P.—B. H. P. | 2.82 | 2.25 | 2.46 | 2.43 | 2.33 |

EFFICIENCIES IN PER CENT.

| | | | | | |
|-------------------------------|------|------|------|------|------|
| 45. Mechanical | 62.5 | 68. | 66.3 | 67.2 | 68.2 |
| 46. Thermal for B. H. P..... | 12.5 | 13.8 | 11.8 | 10.6 | 10.1 |
| 47. Thermal for I. H. P. | 20.1 | 20.4 | 17.7 | 15.8 | 14.8 |

GAS.

| | | | | | |
|--------------------------------------|------|------|------|------|------|
| 48. Fuel Per I. H. P. Per Hour | 23.2 | 23. | 26.5 | 30.3 | 32.5 |
| 49. Fuel Per B. H. P. Per Hour | 37.4 | 33.8 | 40. | 45.1 | 47.8 |

COST OF POWER.

| | | | | | |
|--|------|------|------|------|------|
| 50. Per I. H. P. Per Hour, Cents | 2.79 | 2.76 | 3.19 | 3.63 | 3.90 |
| 51. Per B. H. P. Per Hour, Cents | 4.49 | 4.06 | 4.8 | 5.41 | 5.73 |

VARIABLE GAS MIXTURE.

HEAT BALANCE.

| | | | | | |
|-----|---|--------|--------|---------|---------|
| 52. | Heat Value of Gas Per Cu. Ft., Standard | 589. | 589. | 589. | 589. |
| 53. | Point of Ignition | 22. | 22. | 21. | 21. |
| 54. | Heat Available From Test | 94475. | 87761. | 119861. | 125751. |
| 55. | Heat Used to Produce Max. Pressure | 43420. | 32200. | 49120. | 45300. |
| 56. | Per Cent. Heat Suppression | 54. | 63. | 59. | 64. |
| 57. | Heat Turned Into Work From Diagram | 18980. | 17889. | 18886. | 18650. |
| 58. | Heat Rejected to Jacket Water | 35530. | 30576. | 39930. | 37600. |
| 59. | Heat Rejected to Exhaust | 21190. | 23700. | 22660. | 23400. |
| 60. | Heat Lost by Radiation and Conduction. | 18775. | 15596. | 38885. | 46200. |
| 61. | R | 1.408 | 1.401 | 1.39 | 1.366 |
| 62. | Clearance Per Cent. | 39.9 | 39.9 | 39.9 | 39.9 |

Report of Tests with Variable Point of Ignition.

GAS ENGINE ECONOMY.

VARIABLE IGNITION.

| | | | | | |
|---|-------|-------|-------|-------|-------|
| Barometer | A | B | C | D | E |
| 1. Time Intervals | 14.21 | 14.20 | 14.19 | 14.18 | 14.17 |
| 2. Total Revolutions | 5. | 5. | 5. | 5. | 5. |
| 3. Revolutions Per Min. | 7968. | 7686. | 7644. | 7770. | 7774. |
| 4. Total Actual Explosions | 265.6 | 256.2 | 254.8 | 259. | 259.6 |
| 5. Actual Explosions Per Min. | 3608. | 2664. | 2662. | 2865. | 3399. |
| 6. Ratio of Revolutions to Explosions | 120.2 | 88.8 | 88.7 | 95.5 | 113.3 |
| 7. Explosions Missed Per Min. | 2.21 | 2.89 | 2.88 | 2.71 | 2.29 |
| 8. Explosions Missed Per Min. | 12.6 | 39.3 | 37.7 | 34. | 16.2 |

JACKET WATER.

| | | | | | |
|--|--------|--------|--------|--------|--------|
| 9. Total Weight ..... | ..... | 133. | 157.5 | 149. | 194. |
| 10. Weight, Pounds Per Hour | 327. | 266. | 315. | 298. | 388. |
| 11. Initial Temperature | 64.7 | 65.7 | 64.6 | 67. | 66.6 |
| 12. Final Temperature | 183. | 185. | 177. | 191.6 | 183. |
| 13. Range of Temperature | 118.3 | 119.3 | 112.4 | 124.6 | 116.4 |
| 14. Heat Absorbed, B. T. U. Per Hour | 38684. | 31734. | 35406. | 37131. | 45163. |

AIR.

| | | | | | |
|--|-------|-------|-------|-------|-------|
| 15. Cubic Feet From Meter | 735. | 663. | 630. | 590. | 615. |
| 16. Cubic Feet Per Hour | 1470. | 1266. | 1260. | 1180. | 1230. |
| 17. Temperature | 94. | 95. | 94.7 | 89.7 | 90.7 |
| 18. Pressure, Inches of Water | 1.8 | 2.3 | 2.2 | 2.2 | 2.3 |
| 19. Cubic Feet at 60 degrees Fht., 14.7 lb. | 1342. | 1150. | 1149. | 1082. | 1126. |

GAS.

| | | | | | |
|--|-------|-------|-------|------|-------|
| 20. Cubic Feet From Meter | 124.7 | 84.4 | 84.5 | 88. | 102.1 |
| 21. Cubic Feet Per Hour | 249.4 | 168.8 | 169. | 176. | 204.2 |
| 22. Valve Index Reading | 2. | 2. | 2. | 2. | 2. |
| 23. Temperature | 92.7 | 97.4 | 99.6 | 97.6 | 97. |
| 24. Pressure, Inches of Water | 1.5 | 2.3 | 1.8 | 1.9 | 1.9 |
| 25. Cubic Feet at 60 degrees Fht., and 14.7 lb. | 227.2 | 152.8 | 152.2 | 159. | 184.8 |

RATIOS.

| | | | | | |
|---|------|------|------|------|------|
| 26. Of Air to Gas | 5.9 | 7.54 | 7.54 | 6.8 | 6.1 |
| 27. Value of n in PV ⁿ equal C | 1.54 | 1.31 | 1.38 | 1.44 | 1.38 |

(Continued from page 67.)

VARIABLE IGNITION.

PRESSURES.

| | A | B | C | D | E |
|--|-------|-------|-------|-------|-------|
| 27. At End of Compression | 55.4 | 57.1 | 55.7 | 55.7 | 54.6 |
| 28. At Beginning of Expansion, Max..... | 114. | 209.1 | 214.8 | 222. | 204.9 |
| 29. Mean Effective Back | 4.91 | 4.42 | 4.24 | 4.62 | 4.47 |
| 30. At End of Expansion | 44. | 43.7 | 41.1 | 39.7 | 39.1 |
| 31. Mean Effective | 55.79 | 72.73 | 68.68 | 65.98 | 61.55 |
| 32. If Expansion be Carried to End of Stroke | 40.3 | 40.6 | 38. | 36.6 | 36.2 |
| 33. Net M. E. P. | 51.88 | 68.31 | 64.44 | 61.36 | 57.08 |

TEMPERATURES.

| | | | | | |
|--|-------|-------|-------|-------|-------|
| 34. Of Exhaust, Atmospheric Pressure | 151. | 162. | 168. | 174. | 182. |
| 35. At Release | 1159. | 1200. | 1096. | 1036. | 1028. |
| 36. At Compression | 155. | 181. | 166. | 165. | 157. |
| 37. Maximum Explosion | 1809. | 1894. | 1959. | 2034. | 1859. |

ENERGIES.

| | | | | | |
|--|---------|----------|----------|----------|----------|
| 38. Brake Work, Ft. lbs. | 151467. | 158646. | 157780. | 160380. | 160752. |
| 39. Brake Work, Ft. lbs. Per Hour | 938050. | 9518760. | 9466800. | 9628800. | 9645120. |
| 40. Brake Horse Power | 4.98 | 4.8 | 4.78 | 4.86 | 4.87 |
| 41. B. T. U. equivalent to B. H. P. | 12684. | 12222. | 12168. | 12389. | 12397. |
| 42. Indicated Horse Power | 7.27 | 7.07 | 6.66 | 6.83 | 7.53 |
| 43. B. T. U. equivalent to I. H. P. | 13502. | 17993. | 16949. | 17387. | 19159. |
| 44. I. H. P.—B. H. P. | 2.29 | 2.27 | 1.88 | 1.97 | 2.66 |

EFFICIENCIES IN PER CENT.

| | | | | | |
|-------------------------------|------|------|------|------|------|
| 45. Mechanical | 68.5 | 68. | 71.8 | 71.3 | 64.6 |
| 46. Thermal for B. H. P. | 9.6 | 13.8 | 13.8 | 13.4 | 11.5 |
| 47. Thermal for I. H. P. | 11.1 | 20.3 | 19.2 | 18.8 | 17.8 |

GAS.

| | | | | | |
|--------------------------------------|------|------|------|------|------|
| 48. Fuel Per I. H. P. Per Hour | 34.3 | 23.8 | 25.4 | 25.8 | 27.1 |
| 49. Fuel Per B. H. P. Per Hour | 50.1 | 35.2 | 35.3 | 36.2 | 42. |

COST OF POWER.

| | | | | | |
|--|------|------|------|------|------|
| 50. Per I. H. P. Per Hour, Cents | 4.12 | 2.85 | 3.04 | 3.09 | 3.26 |
| 51. Per B. H. P. Per Hour, Cents | 6.02 | 4.22 | 4.24 | 4.35 | 5.05 |

VARIABLE IGNITION.

HEAT BALANCE.

| | | | | | |
|-----|--|---------|--------|--------|---------|
| 52. | Heat Value of Gas B. T. U. Per Cu. Ft., Standard | 580. | 580. | 580. | 580. |
| 53. | Point of Ignition | 5. | 10. | 15. | 25. |
| 54. | Heat Available From Test | 131776. | 88624. | 88276. | 107284. |
| 55. | Heat Used to Produce Max. Pressure | 18780. | 31950. | 33600. | 40000. |
| 56. | Per Cent. Heat Suppression | 86. | 64. | 62. | 63. |
| 57. | Heat Turned Into Work From Diagram | 18502. | 17993. | 16949. | 19159. |
| 58. | Heat Rejected to Jacket Water | 38684. | 31734. | 35406. | 45163. |
| 59. | Heat Rejected to Exhaust | 30150. | 20160. | 18300. | 21360. |
| 60. | Heat Lost by Radiation and Conduction. | 44440. | 18737. | 17620. | 21602. |
| 61. | R | 1.38 | 1.363 | 1.364 | 1.355 |
| 62. | Clearance Per Cent. | 39.9 | 39.9 | 39.9 | 39.9 |

VARIABLE COMPRESSION.

| | | | | |
|---|-------|--|--|--|
| Barometer | 14.16 | | | |
| 1. Time Intervals | 5. | | | |
| REVOLUTIONS AND EXPLOSIONS. | | | | |
| 2. Total Revolutions | 7928. | | | |
| 3. Revolutions Per Min. | 264.3 | | | |
| 4. Total Actual Explosions | 3518. | | | |
| 5. Actual Explosions Per Min. | 117.3 | | | |
| 6. Ratio of Revolutions to Explosions | 2.23 | | | |
| 7. Explosions Missed Per Min. | 14.9 | | | |

JACKET WATER.

| | | | | |
|--|--------|--|--|--|
| 8. Total Weight | 211. | | | |
| 9. Weight, Pounds Per Hour | 422. | | | |
| 10. Initial Temperature | 65. | | | |
| 11. Final Temperature | 179. | | | |
| 12. Range of Temperature | 114. | | | |
| 13. Heat Absorbed, B. T. U. Per Hour | 48108. | | | |

AIR.

| | | | | |
|--|-------|--|--|--|
| 14. Cubic Feet From Meter | 600. | | | |
| 15. Cubic Feet Per Hour | 1200. | | | |
| 16. Temperature | 79. | | | |
| 17. Pressure, Inches of Water | 2.06 | | | |
| 18. Cubic Feet at 60 degrees Fht., 14.7 lb. | 1121. | | | |

GAS.

| | | | | |
|--|-------|--|--|--|
| 19. Cubic Feet From Meter | 108.1 | | | |
| 20. Cubic Feet Per Hour | 216.2 | | | |
| 21. Valve Index Reading | 2. | | | |
| 22. Temperature | 92. | | | |
| 23. Pressure, Inches of Water | 2.07 | | | |
| 24. Cubic Feet at 60 degrees Fht., and 14.7 lb. | 197.2 | | | |

RATIOS.

| | | | | |
|-------------------------------------|------|--|--|--|
| 25. Of Air to Gas | 5.68 | | | |
| 26. Value of n in PVn equal C | 1.41 | | | |

GAS ENGINE ECONOMY.

| | | | | |
|--|--------|--------|--------|--------|
| | D | E | F | G |
| Barometer | 14.16 | 14.16 | 14.15 | 14.13 |
| 1. Time Intervals | 5. | 5. | 5. | 5. |
| 2. Total Revolutions | 7928. | 7945. | 8014. | 7962. |
| 3. Revolutions Per Min. | 264.3 | 264.6 | 267.1 | 265.4 |
| 4. Total Actual Explosions | 3518. | 3483. | 3708. | 3353. |
| 5. Actual Explosions Per Min. | 117.3 | 116.1 | 123.6 | 111.7 |
| 6. Ratio of Revolutions to Explosions | 2.23 | 2.2 | 2.08 | 2.29 |
| 7. Explosions Missed Per Min. | 14.9 | 16.2 | 9.9 | 21. |
| 8. Total Weight | 211. | 200.5 | 207.5 | 183. |
| 9. Weight, Pounds Per Hour | 422. | 401. | 415. | 366. |
| 10. Initial Temperature | 65. | 64. | 66. | 67. |
| 11. Final Temperature | 179. | 177. | 182. | 179. |
| 12. Range of Temperature | 114. | 113. | 116. | 112. |
| 13. Heat Absorbed, B. T. U. Per Hour | 48108. | 45313. | 48140. | 40992. |
| 14. Cubic Feet From Meter | 600. | 610. | 600. | 575. |
| 15. Cubic Feet Per Hour | 1200. | 1220. | 1200. | 1150. |
| 16. Temperature | 79. | 89.6 | 97. | 99. |
| 17. Pressure, Inches of Water | 2.06 | 2.1 | 2. | 2. |
| 18. Cubic Feet at 60 degrees Fht., 14.7 lb. | 1121. | 1118. | 1085. | 1034. |
| 19. Cubic Feet From Meter | 108.1 | 112.2 | 119.7 | 104.7 |
| 20. Cubic Feet Per Hour | 216.2 | 224.4 | 239.4 | 209.4 |
| 21. Valve Index Reading | 2. | 2. | 2. | 2. |
| 22. Temperature | 92. | 94.4 | 100. | 104. |
| 23. Pressure, Inches of Water | 2.07 | 1.96 | 2.04 | 1.8 |
| 24. Cubic Feet at 60 degrees Fht., and 14.7 lb. | 197.2 | 204. | 215.5 | 186.5 |
| 25. Of Air to Gas | 5.68 | 5.5 | 5.03 | 5.55 |
| 26. Value of n in PVn equal C | 1.41 | 1.44 | 1.46 | 1.55 |

THE NEBRASKA BLUE PRINT.

(Continued from page 71.)

VARIABLE COMPRESSION.

| | D | E | F | G |
|--|-------|-------|-------|-------|
| PRESSURES. | | | | |
| 27. At End of Compression | 48.3 | 54.9 | 58.9 | 62.3 |
| 28. At Beginning of Expansion, Max..... | 166.5 | 157.7 | 197.4 | 228.6 |
| 29. Mean Effective Back | 4.44 | 4.58 | 4.66 | 4.38 |
| 30. At End of Expansion | 36.3 | 37.7 | 34.2 | 35.7 |
| 31. Mean Effective | 58.74 | 60.4 | 55.9 | 58.6 |
| 32. If Expansion be Carried to End of Stroke | 33.5 | 34.75 | 31.6 | 32.7 |
| 33. Net M. E. P. | 54.3 | 55.82 | 51.24 | 54.22 |

TEMPERATURES.

| | | | | |
|--|-------|-------|-------|-------|
| 34. Of Exhaust, Atmospheric Pressure | 152.6 | 145. | 156. | 154. |
| 35. At Release | 890. | 948. | 834. | 880. |
| 36. At Compression | 149. | 199. | 200. | 194. |
| 37. Maximum Explosion | 1639. | 1433. | 1750. | 1959. |

ENERGIES.

| | | | | |
|--|----------|----------|----------|----------|
| 38. Brake Work, Ft. lbs. | 163662. | 163848. | 165406. | 164346. |
| 39. Brake Work, Ft. lbs. Per Hour | 9819750. | 9830880. | 9924378. | 9860616. |
| 40. Brake Horse Power | 4.96 | 4.96 | 5.01 | 4.98 |
| 41. B. T. U. equivalent to B. H. P. | 12622. | 12636. | 12756. | 12674. |
| 42. Indicated Horse Power | 7.42 | 7.56 | 7.38 | 7.06 |
| 43. B. T. U. equivalent to I. H. P. | 18899. | 19230. | 18789. | 17972. |
| 44. I. H. P.—B. H. P. | 2.46 | 2.60 | 2.37 | 2.08 |

EFFICIENCIES IN PER CENT.

| | | | | |
|-------------------------------|------|------|------|------|
| 45. Mechanical | 66.6 | 65.8 | 68. | 70.5 |
| 46. Thermal for B. H. P. | 10.4 | 11.3 | 10.8 | 12.4 |
| 47. Thermal for I. H. P. | 16.1 | 17.2 | 15.9 | 17.6 |

GAS.

| | | | | |
|--------------------------------------|------|------|------|------|
| 48. Fuel Per I. H. P. Per Hour | 29.1 | 29.7 | 32.4 | 29.6 |
| 49. Fuel Per B. H. P. Per Hour | 43.5 | 45.3 | 47.7 | 42. |

COST OF POWER.

| | | | | |
|--|------|------|------|------|
| 50. Per I. H. P. Per Hour, Cents | 3.5 | 3.56 | 3.89 | 3.56 |
| 51. Per B. H. P. Per Hour, Cents | 5.22 | 5.44 | 5.73 | 5.04 |

VARIABLE COMPRESSION.

HEAT BALANCE.

| | | | | | |
|-----|---|---------|---------|---------|---------|
| 52. | Heat Value of Gas Per Cu. Ft., Standard | 616. | 549. | 549. | 549. |
| 53. | Point of Ignition | 25. | 24. | 24. | 20. |
| 54. | Heat Available From Test | 121475. | 111996. | 118310. | 102388. |
| 55. | Heat Used to Produce Max. Pressure | 39280. | 31100. | 39100. | 37610. |
| 56. | Per Cent. Heat Suppression | 62.5 | 72.4 | 67. | 63. |
| 57. | Heat Turned Into Work From Diagram | 18899. | 19230. | 18789. | 17972. |
| 58. | Heat Rejected to Jacket Water | 48108. | 45313. | 48140. | 40992. |
| 59. | Heat Rejected to Exhaust | 20580. | 21080. | 18050. | 16220. |
| 60. | Heat Lost by Radiation and Conduction. | 33886. | 26373. | 33331. | 27204. |
| 61. | R | 1.471 | 1.428 | 1.364 | 1.329 |
| 62. | Clearance Per Cent. | 48.3 | 44.5 | 39.7 | 36.3 |

Features of All Cable Distribution.

By Arthur Bessey Smith, Instructor of Telephone Engineering, Purdue University.

In the older days of telephony the subject of wire plant design was not very carefully worked out. To begin with, no one had any idea of the size to which the business would grow and all parts of the plant were selected with only the present, or the very immediate future, in view. This small beginning proving successful, the business soon outgrew the original installation and required a larger switchboard, more cross arms and more wire.

Soon the lowest cross arm reached the limit and longer, heavier poles had to be substituted, although the first poles were yet sound below the ground line and had not paid for themselves. It is true that these first poles were re-set elsewhere as guy stubs or on side lines, but the cost of labor for making the change often exceeded the value of the poles. This process of rebuilding has been going on in many exchanges all over the country ever since their beginning. Each year the owners thought that the limit of growth had been reached—each succeeding year saw the circle of subscribers widened and the costly process of rebuilding repeated.

That so many good dollars should be wasted in needless building and rebuilding is to be regretted, but it is not without a cause. Coupled with the belief that the business would not grow much larger was the shyness felt by moneyed men against giving their support to a new and untried venture. Again, the forms of apparatus and methods of installation were in an extremely unsettled state, due to the inexperience of mankind as a whole in dealing with this new agency. It is therefore a cause for congratulation that no more money was invested in the older apparatus and methods, which have been rendered obsolete by the inventions of recent years. I think we may safely say that the first transition period has been passed, that apparatus and meth-

ods are entering an age of standardization, and that we may with profit enlarge our view, count the cost and build for the future.

The time has come when the wire plant must be designed as carefully as the switchboard. Estimates must be made, all factors counted in and the outside construction designed to accommodate the traffic for an indefinite future without radical change in its design or the waste of labor or material. Additional cables may need to be pulled in but original work should not need to be destroyed before it has outlived its usefulness.

One of the latest developments of the wire plant is the idea of making the distribution entirely by means of cables, dispensing with all open wires. The cable idea has been used for some time in the main leads, where to carry all the circuits on cross arms would be unsightly, dangerous, or impossible. The circuits were always carried on cross arms in the form of open wires from the end of the cable to the points nearest the individual subscribers. The troubles of open wires need scarcely be enlarged upon here. Crosses, short circuits and grounds are of daily occurrence. The difficulty of securing permission to trim valuable shade trees to clear wires carried on five 10-pin cross arms is no small thing and the owner cannot be blamed for objecting. Consent for the narrow space occupied by a 50-pair cable is easily secured.

To make the entire plant in cable necessitates a certain density of population, for it is evident that it will not pay to string cable for one or two subscribers up numerous side streets. But the advantages of having all circuits protected from the elements are great and important enough to make profitable the use of much smaller cables than many engineers have been accustomed to advise.

Before laying out an all cable plant it is customary to make a preliminary survey of the city. This survey makes note of the number of people in each block and the number of telephones already in use. The presence and nature of trees, the hills and hollows, the character of the soil, the location of trolley and high tension lines are very important parts of the survey. A factor often overlooked is the direction of probable growth of residence districts which may severely overload certain parts of the cable system at some future day.

As much of the above data as is practicable should be recorded on a map of the city drawn to scale. Especially to be

noted are the distribution of population and present telephones and the poles of other companies. From this map an estimate is made of the number of subscribers that may be secured in each block.

At this point the question of kind of service is introduced in the problem. If all subscribers are to be placed on individual lines the engineer will estimate accordingly. But if party line service is to be offered to the people, fewer circuits will need to be provided for, but each must be available at more than one point. This makes necessary the multiple tap system, in which each pair is tapped out at as many terminal boxes as deemed advisable. If four-party service is considered, each pair designed for such service should appear at least four times. As the service will doubtless be mixed—individual, two-party, four-party, and rarely ten-party; the pairs should be of all grades of multiples. It should be kept in mind that even an individual line should appear at several points to secure flexibility.

It is a good practice in party line work to avoid placing two subscribers on the same circuit if they live near each other. People have as a rule more objection to being on the same line with those they know than with total strangers who live at a distance. Hence, the rule not to put two subscribers on the same line if their drop lines come out of the same can. However, cases often occur in which the saving of drop line make it advisable to break the rule.

The exact proportion of multiplying is very uncertain and must be decided by local conditions. Even if the entire exchange is to be made up of individual lines, each pair in the cable should appear at several places. But it is my opinion that the region immediately adjoining the exchange can be served best by pairs not multiplied with those that run a considerable distance away. Many of them may be direct pairs—appearing only once.

It is readily seen that such a scheme presupposes a certain ultimate capacity. This figure is not as definite as the capacity of a switchboard because development does not always go in the expected direction. The number of subscribers in one locality may increase much more than expected while another neighborhood may be scarcely developed at all. This gives rise to the necessity of so designing the cable lay out that by running a relief cable

from the office to a given junction point, the excess load may be carried. Certain pairs that branch from the old cable may be cut loose and spliced into the new cable, leaving both old and new cables with considerable room to spare. The gain of this operation will be increased if the old cable is quite heavily multiplied, especially beyond the junction point.

Since no open wire is to be employed the question of how small a cable we shall use now comes up. The best practice seems to indicate 10 pairs as the limit. As far as the first cost goes, it may be decided by estimating the number of circuits that will be used in the near future. If the cable is not used, the circuits must be carried in the form of drop wire, that is, rubber covered wire, braided and twisted in pair. If the cost of the drop wire necessary to carry the circuits is equal to the cost of 10-pair cable, it will pay to install the cable, unless the run be very short. But if it falls very much below, it is doubtful economy to string a 10-pair cable with its added expense of terminal box, which may have to be idle for years to come.

The question of placing cable underground is also of great importance. For the smaller cables in residence districts it is vastly cheaper and handier to erect them on poles, but the larger cables should be accorded the protection of underground conduit if it is a possibility to do it. In some cases, especially cities underlaid with rock, this may entail considerable expense. But a single accident to a 200- or 300-pair cable may wipe out the profits of years.

To protect the cable and its connected apparatus from lightning, the carbon block arrester has never yet been excelled and should always be installed in the terminal boxes. Fuses should also be provided to take care of heavy current.

The arrangement of guy wires is of the utmost importance, especially when the cable runs in the neighborhood of power lines. Leakage from these circuits is always seeking a good path to earth and as the cable sheath is nearly always in good connection with the same, it frequently suffers.

The following case came under my observation and illustrates this point very forcibly:

On a certain pole, the cable supplying the terminal box came up from underground along the side of the pole and was covered

by a galvanized iron cover. Near the top of the pole an eyebolt passed through with the washer and nut in contact with the galvanized cover. A guy was fastened in the eye of the bolt running obliquely downward to another pole occupied jointly by the street railway and the fire alarm, where it was attached by being wrapped around the pole. A fire alarm signal box was mounted below the attachment of the guy, with a pipe extending both down into the earth and up toward the top, which pipe carried the wires. An insulating joint was inserted a short distance below the box, effectually insulating the box and upper pipe from the earth. The upper pipe rested against the telephone guy and also against the suspension wire of the street railway. The latter had a strain insulator which insulated the trolley wire.

But one morning in a thunder storm this strain insulator failed, and allowed the 500-volt trolley current to flow along the suspension wire to the fire alarm pipe. Passing down the pipe it crossed to the telephone guy, up the guy, through the eyebolt, on to the galvanized iron cover, down to the first point where the cover touched the cable. From its contact with the cable the path to earth was good, but the cable was burned off at the contact point. The faulty strain insulator was consumed and a hole burnt in the galvanized cover.

Great care should be exercised to insure that no such set of combinations can exist, for sooner or later it may cause trouble, no matter how round-about the path may be. The only safety is in having all guys absolutely clear.

Almost as bad is the annoyance caused by trees rubbing holes in the cable sheath. While for a town full of shade trees, the cable lead requires far less trimming than an open wire lead, this does not mean that we may put up our cable without any trimming. A branch of suitable size resting on the sheath, or one that may blow against it with the wind, will rub its way through the lead, and let in the wet at the least desirable time. The cable should hang clear of all branches at all times—a point that cannot be too strongly emphasized. The smaller sizes of cable are especially susceptible to this danger, the 10-pair being the worst. In cases where permission to trim cannot be secured, a wooden or metal shield may be placed around the cable, firmly clamped to the messenger. The shield must be of ample length, for if too short,

the limb of the tree will swing past the end, catch on the return motion and in time cause serious damage. The use of a tree shield is only an expedient and should never be used if it is a possible thing to get a permit to trim. But the main point is to protect the cable. It is in the outside plant where the losses of an exchange come in, and it must be jealously watched and cared for.

On the whole, the advent of the all cable system has brought to the front a number of interesting points. The investment at the start is somewhat heavy and some parts of the cable lay out may run for a number of years before returning proper interest on the money invested. Since the whole of the outside wires is in the form of cables, the question of cable troubles will be the most important in maintenance. These are more difficult to locate and repair than open wire troubles, and if not properly installed, cable will be an endless source of trouble. Trees will be continually rubbing holes into the sheath especially on the smaller cables which run up side streets, and a hole means the wetting of all the pairs in that branch, affecting also all the pairs to which they are multiplied. The subscribers' lines will have a higher capacity than if a considerable portion were open wire, and this is not advantageous when long distance telephony is considered, although it may allow good local service.

If, on the contrary, the cable is well put up, properly bonded in the underground, properly guyed in the aerial, guys clear from danger of crosses, sheath clear from trees or fully protected, all splices conscientiously boiled out and sealed up, and proper electrical protection provided in the terminal boxes the line troubles will be practically nothing. The absence of crosses, shorts, and grounds will be appreciated by the manager as well as the troubleman. New subscribers are more readily connected, as the only line to be strung is the twisted pair from the terminal box to the house. It reduces the bugbear of moving subscribers.

The depreciation is very low. In a word, the total cost of operation and maintenance is materially reduced.

In these days more attention is being paid to details and more conscience is being put into the execution. In view of this I believe that the future will see the number of all cable plants very much increased.

The Calculation of Forfeits or Bonuses for High Duty Pumping Engines.

By Prof. C. R. Richards.

Modern high duty pumping engines are wonderfully efficient machines. The uniformity of load and the continuity of service is conducive to the highest sustained thermal efficiencies. Manufacturers of such machines have used every possible method of decreasing the consumption of heat, and in consequence, a high duty pumping engine is a very expensive piece of apparatus. If the saving of fuel secured by such a pump will yield a substantial return on the investment necessary in excess of that required by a cheaper and less efficient pump, then, and only then, is the purchase of the more expensive machine justified. Assuming that the purchaser has determined that a certain duty is necessary to warrant the purchase of so expensive a machine, he must be given some reasonable assurance that this duty will actually be attained in service. A failure to reach this predetermined duty is an actual damage to the purchaser, and he should be reimbursed for such damages as can fairly be shown to have been incurred. On the other hand, if a predetermined duty will yield a profitable saving to the purchaser, a higher duty will actually increase his net saving or profit, and he can afford to give a bonus to the manufacturer who is able, by the superior design and workmanship of his machine, to produce a more efficient pump than had been called for.

In the preparation of specifications for pumping engines, it is not uncommon to require a guarantee of a certain number of millions of foot-pounds of work to be done with a consumption of one hundred pounds of coal, or one thousand pounds of steam, or preferably, of one million British thermal units. It is often

further specified that should the actual duty developed during the duty trial be below that guaranteed, a forfeit shall be deducted from the contract price, and should the duty exceed that guaranteed, a bonus shall be paid by the purchaser to the manufacturer. The problem of calculating the forfeit or bonus is a somewhat interesting problem in engineering finance.

Let D = the guaranteed duty in millions of foot-pounds of work done per million B.t.u.'s consumed.

W = the actual work done per day in foot pounds = the total weight of water lifted in 24 hours multiplied by the total head or height lifted.

n = the number of million foot pounds of work done in excess of, or below the guarantee.

H = the total heat per pound of steam, under the conditions of initial and back pressure or feed water temperature named in the guarantee. The feed water temperature would generally be considered the same as the temperature corresponding to that of saturated steam under the back pressure on the engine.

E = the number of pounds of water evaporated in the boilers per pound of coal, under ordinary conditions of service.

C = the cost of coal in dollars per ton of 2000 pounds.

d = depreciation of pumping engine in hundredths.

r = repairs on pumping engine in hundredths.

i = interest on investment in hundredths.

Evidently:

$\frac{W}{D}$ = the heat consumption in million B. t. u. per day under the duty guaranteed.

and $\frac{W}{D \pm n}$ = the heat consumption for any other duty above or below the guarantee.

If n be below the guarantee, the extra heat required per day, in excess of the guarantee will be

$$X = \frac{W}{D-n} - \frac{W}{D} = - \frac{n W}{D(D-n)} \text{ million B. t. u. and}$$

the yearly cost of extra coal will be

$$\frac{360 X C}{2000 H E} = \frac{0.18 X C}{H E} \text{ dollars.}$$

Since this expense will be incurred yearly during the life of the pump, or $1/d$ years, the total damage because of the failure to meet the guarantee—i. e., the forfeit—is

$$0.18 \frac{X C}{H E d} \text{ dollars.}$$

The full sum of the damage might be deducted from the contract price, or, if the purchaser is willing to “discount” the above forfeit for cash, the actual forfeit would be such as would at the end of $1/d$ years at compound interest, equal the above total damage, or on this basis, the forfeit would be

$$0.18 \frac{X C}{H E d (1 + i)^{\frac{1}{d}}} \text{ dollars.}$$

It is probable that in general, the full amount of the damage would be collected, rather than the discounted damage. This might be considered as an extra penalty for failure to meet the guarantee.

Should the duty developed be above the guarantee, then the heat saved per day will be

$$Y = \frac{W}{D} - \frac{W}{D+n} = \frac{n}{D(D+n)} W \text{ million B. t. u.}$$

and the total saving per year would be

$$0.18 \frac{Y C}{H E} \text{ dollars.}$$

Now, obviously, this saving represents to the purchaser the returns from an investment which yields i interest, and which is subject to an average depreciation and repair rate of $d+r$, hence the value of the extra investment or the *bonus*,—is

$$0.18 \frac{Y C}{H E (d + r + i)} \text{ dollars.}$$

If the duty were expressed in terms of steam used, then X and Y would be thousands of pounds of steam, and the forfeit or bonus would be respectively

$$0.18 \frac{X C}{E d} \text{ and } 0.18 \frac{Y C}{E (d + r + i)}$$

An inspection of the values of X and Y shows that they decrease with increasing values of D for a constant value of n ; and further that X increases and Y decreases with n . Generally the bonus or forfeit is specified as so many dollars for each million foot-pounds, or major fraction thereof, above or below the

guarantee. It should be noted, however, that X and Y, and hence the forfeit or bonns, can only be exactly determined when n is known. The difference is small, and the forfeit or bonus per million foot pounds departure from the guarantee can be determined with sufficient accuracy by assuming $n=1$.

As an illustration of the application of the above principles, the 30,000,000 gal. pumping engine furnished the City of Boston for their Chestnut Hill Station by the Allis-Chalmers Co., was guaranteed to give a duty of 150,000,000 foot-pounds per 1,000 pounds of commercially dry steam, when pumping at its rated capacity against a head of 140 feet. The specifications provided for a bonus of \$1,000.00 for each million foot-pounds above and a forfeit of \$2,000.00 for each million foot-pounds or fraction thereof below the guarantee. While the writer is not familiar with the method employed to determine these sums, a close approximation is obtained as follows: Assuming $d=.05$; $i=.01$; $n=1$; $E=10$ lbs.; $C=\$4.00$; $W=30,000,000 \times 7.5 \times 140$ equals 31,500,000,000 foot pounds per day. Therefore:

$$0.18 \frac{Y C}{E (d + r + i)} = \frac{18 \times 31500 \times 4 \times 1000 \times 100}{100 \times 150 \times 151 \times 10 \times 10} = \$1001.32$$

$$\text{and } 0.18 \frac{X C}{E d} = \frac{18 \times 31500 \times 4 \times 1000 \times 100}{100 \times 150 \times 149 \times 10 \times 5} = \$2029.53$$

It is interesting to note that the duty obtained with the above pump was 176,051,500 foot-pounds per 1,000 pounds of moist steam, and that the bonus earned was consequently \$26,051.50. The duty per 1,000 pounds of dry steam was 178,497,000 foot-pounds, and per 1,000,000 B. t. u. was 163,925,300 foot-pounds.

Gear Tables.

The first two pages of calculations were compiled by the writer several years ago while actively engaged in gear designing and were put in this form for convenient reference.

The proportions here given have been used with all classes of gears for mill work and have given entire satisfaction.

The third page of calculations were made by the students in Mechanism, being carefully checked and put into the present form by Mr. A. R. Wilson to whom full credit should be given.

The dimensions refer to cast gears only, and would therefore not be suitable where back lash or noise would be objectionable.

Yours truly,

THOMAS DAVIS.

GEAR TABLES.

87

Practical Method of Constructing Concrete Curb and Gutter.

Surveying. The ordinary methods of surveying obtains here. Corners must be carefully looked up and monuments, if any in the street, tied out in the customary way. Stakes must be set for the contractor, these will serve both for

Line and grade stakes. These should be good two inch oak stakes (see G of the sketch) and set firmly behind the curb, two feet back from the face of the curb gives good results. They should be driven exactly to grade and tacked true to line. A good plan is to first put in the stakes at each block corner and "shoot" in the intermediates about fifty feet apart by fixing the target on the rod at the height of the instrument above the stake over which it stands, then set the rod with its fixed target upon the corner stake at the other end of the block, sight the instrument on the target and clamp. Set all the intermediate stakes to the same target. Also while the transit is set, put in the line tacks. It is important that these stakes be set to the exact grade of the top of the curb, even though holes have to be dug to do so. A post hole auger will prove of service in such cases, and long stakes should be provided for places requiring to be filled.

Grading the street. The soil should be taken out to within about two inches of the finished sub-grade, conforming exactly to the crown of the street. In case of a fill, the earth should be spread in layers of six or eight inches and each layer rolled to prevent further settling after the pavement has been laid.

Rolling. After the grading is within the two inches above spoken of a twelve or fifteen ton steam roller should be run over the street. It is surprising how many soft places will be found. Ditches made for gas pipes years before will settle under the heavy roller. All such depressions will be filled and rerolled. The rolling should extend at least a foot over

the space to be excavated for the curb and gutter. If the rolling is thorough at this time no further rolling will be necessary.

Excavating Under the Curb and Gutter. The line and grade stakes being in position it is an easy matter for the foreman to measure over the proper distances, set stakes and with a spirit level get the right height to fasten his lines for the excavators. These with their shovels dig out the earth to the required depth, each one having a stick to measure down from the lines set by the foreman. The excavated earth is thrown on the bank outside the curb to be later used for covering.

Forms. Three inch commercial size Oregon Fir lumber dressed upon both sides to two and one-half inches will make good forms. Stiff forms are absolutely essential to good work and then the use of stiff plank is good economy as labor and time are saved in driving stakes and as nailing is not necessary the planks can be used over again without destruction. The sketch and photographs will show the general character of the forms. Division sheets made of three-sixteenths inch steel answer also for templets. Each back board and each gutter board is notched to receive these templets, which in turn hook over the boards thus helping to hold the forms to place. The gutter and back boards have holes bored in their ends in which one-half inch iron pins are inserted to hold the boards in line with each other. The planks should be made so that they may be used either side to the wet concrete then by frequent changing warping to a great extent will be prevented. The same statement is true of face boards.

Setting the forms. Measure over the proper distances from the line stakes and drive good solid stakes, and let them extend three or four inches higher than the gradestakes. Stretch a tight line between these exactly over the edge of the back board, set the back boards to approximate position and stake at ends and middle true to the stretched line, the stake may cover the joint between the boards thus one stake will answer for two boards. Shim up these back boards to place with bits of stone, or better, brick, and continue to adjust till true to line and grade. Three sighting sticks will be of advantage. Set both ends of a block of back boards to grade with a spirit

level (see sketch.) Fasten a sighting stick up on one end, take a second stick to the other end and by sighting at the first, direct a workman who holds the third stick on top of the back board and shims up the plank until a true line is attained. The back boards thus lined up should be checked at each line-grade stake. Having the back board in place, which is the most particular part of the work, the gutter planks are next set and leveled up by an L-shaped gage stick and a spirit level. The L seen lying on the ground in the sketch, is then placed on the gutter board and the other end on the back board, the level upon the whole, and shimed to place. The templets are then put in when all inside stakes may be removed. Round corners are easily made by using sheet steel forms stiffened with small angle irons along the top and bottom. An eight foot radius makes a good appearing corner.

Cinders.—For the purpose of drainage clean soft coal cinders are to be preferred although broken stone and gravel will give satisfactory results. About six inches in depth thoroughly flooded and rammed should prove sufficient. The forms being in place the proper grading of the cinders is easily accomplished.

Concrete.—The concrete used in the curb and gutter is generally of two classes, that for the body and that for the wearing surface. The body is made up of leaner mixtures and of larger stone. Engineers disagree as to the best size of stone to be used,

but if the matrix is properly proportioned, with just sufficient sand to fill the voids of the stone and sufficient, or a little more than sufficient cement to fill the voids of the sand the larger stone will prove cheaper and just as good as the smaller sizes. After the body concrete has been thoroughly rammed it is "screeded" off with a "screed" made by fastening a piece of steel, one-eighth inch thick, to a straight edge long enough to reach from one templet to the next, the steel plate being a little shorter than the distance between templets, extends three-fourths of an inch below

the straight edge and below the top of the templets. If the steel plate is notched with half-inch notches like a cross-cut saw it will be found to work easier and leave a roughened surface to which the top coat will better adhere.

Body of the Curb.—A face board about two and one-half or three inches thick is clamped to the back board and templets and filled about half full of concrete which should be pushed away from the face board with a shovel. The face board is then plastered with wearing surface material to the required thickness, the concrete which was shoved back now brought against the plaster to hold it in place and the entire curb filled to the top, rammed, filled again and again rammed to within three-fourths of an inch of the top. Wearing surface material makes up the remaining part, which is floated and properly rounded by radius trowels. The face boards should be rounded to fit the templets

on two diagonally opposite edges so they may be used with either side to the curb to prevent warping. There should be three of them butted end to end, two of which are always kept clamped. The third or last one after having been filled is loosened by removing the clamps and thrusting a small bar between the end of it and the next face board ahead, thus pushing it endwise. Frequent sprinkling of the face board will prevent sticking.

Wearing Coat.—The "topping" or wearing coat is made up of screenings or sand or a mixture of both which will pass a No. 6 sieve and is considerably richer in cement, say one and one-half to one, than the body concrete. It should be mixed in a box to the consistency of stiff mortar and floated on to a uniform thickness of three-quarters of an inch and brought to a true surface by running a straight edge over the templets.

Finishing.—The finishers follow up and float and trowel the curb and gutter until all air bubbles are removed. Excessive trowling should be avoided as it brings neat cement to the surface which is liable to produce air cracks. The templets are now pulled and the edges jointed. The final finish may be by brushing which removes all gloss and lessens liability to air cracking.

Covering.—After sufficient time is given for the cement to set the top surface should be covered with the earth thrown on

the bank when excavating the ditch. The form planks may be removed after twenty-four hours and the whole curb and gutter carefully covered with earth. In dry weather the earth covering should be wet down frequently. It is a good plan to have the night watchman do that every night for about one week.

This completes the curb and gutter work. The curb being in place furnishes an excellent basis for setting stakes for the sub-grade work, the concrete and the final paving.

A Few Points for the Inspector.—Watch the alignment. Otherwise good work will look bad if not in line, or if depressions occur the gutter may not properly drain. See that the cinders are sufficiently tamped, otherwise settling may take place after the street is paved. Thorough mixing of the cement must be insisted upon. More work is defective through this cause than through scamping the quality of cement. With mechanical mixers there is less occasion for fear. Thorough ramming of the concrete to eliminate all voids. This is hard work and workmen will slight it if given a change. See that you get the proper thickness of facing or wearing material. The faces of the curb is where it usually runs thin. Do not allow the finisher to use neat cement for dryer. Let him use material in the same proportion as the "topping" only screened through a finer sieve. See that the templets are kept clean that when they are pulled the joint is left smooth not jagged. See that the finisher after pulling the templet properly trowles the joint, neither pushing it down till the stones are in contact, as a clear space should be left for contraction and expansion, nor should he leave the edges ragged. Examine the concrete immediately after the forms have been removed, if it is not of a uniform color there has been improper mixing, if it is too porous, improper tamping or wrong proportions.

GEO. R. CHATBURN,
Professor of Applied Mechanics.

General Notes.

What the Engineering Society is Doing.

The Engineering Society is passing through the most progressive year of its existence. Never before has such interest been displayed and such good crowds been present at business meetings as well as smokers. The active membership has been increased to about one hundred and forty with many more applications for membership still on file.

The reason for such great activity in the society and its increased membership may be partly due to the fact that the proportion of students registering for engineering this year far exceeds that of former years. At the beginning of the present school year about three-fourths of the male students entering the University registered in the engineering groups.

Unfortunately the equipment has not increased in proportion and until a new engineering building is secured the department will be grievously handicapped. If the Society has any strength as an organization a part of its energy might well be directed in agitating the question of obtaining a new building.

The first meeting of the Society in 1905 was called to order on October 11, and the following officers were elected.

| | |
|-------------------------------|----------------|
| President | Cyrus L. Cole. |
| Vice-President | A. G. Hastie. |
| Recording Secretary | C. K. Smith. |
| Treasurer | A. E. Palen. |
| Corresponding Secretary | O. A. Ellis. |

Throughout the year the usual number of short talks have been given by professors and students who have had practical experience. On December 13, 1905, State Surveyor Harvey gave a very interesting talk on his earlier experiences. Commencing January 22, 1906, Samuel S. Wyer, M. E., of Columbus, Ohio, gave a series of three lectures on "Producer Gas and Gas Pro-

ducers." Mr. Wyer explained in detail the construction and operation of gas producers and the use of producer gas. He predicted a very extensive use of producer gas engines on locomotives and battleships in the near future.

It is our hope that in a year or two the University will provide a course of lectures by prominent engineers in the different lines to supplant a part of the text book work of the senior year.

Until this can be done it should be the aim of the Society to provide during the school year, a course of lectures by representative engineers.

The Society has in the past been very fortunate in having with such men as Goss, Waddell and Corthell, and it is to be hoped that the engineering students in the University of Nebraska will, in the following year, become more intimately acquainted with our best engineers and their works.

A committee of the Society is at present in communication with several prominent engineers, and expect to procure one or two of them to lecture before the Society this spring.

And now a word in closing. Be loyal to your Alma Mater and the Society. If you are asked to contribute something of your work and experience to the Society in the form of an article or a talk, give it and be glad of the chance to show your appreciation of what the engineering department of the University has done for you.

Alumni.

NOTE.—The following is a complete list of the graduates of the University in Engineering courses. There are included a certain number of graduates from other departments who took engineering subjects as electives and entered engineering pursuits after graduation; also a few students who left school and who are now engaged in engineering work. The addresses given are believed to be correct to date, March, 1906. The editors will be pleased to receive any corrections or additions which will be filed for the use of their successors.

- Abry, B. B., B. Sc., U. of Ill. '00. Deceased.
Albers, Juergen, B. Sc. C. E., '93.
Anderson, C. E., B. Sc. E. E., '98. Craig, Nebr.
Andrews, A. H., B. Sc. C. E., '98. Deceased.
Arnold, B. J., E. E., '97. Chicago, Ill. Pres. Arnold Elect. Power Station Co.
Anderson, E. E., B. Sc. C. E., '05. Asst. Supt. of Construction Uni. of Nebr. Lincoln, Nebr.
Andrew, J. W., McCook, Nebr. Asst. Road Foreman, C. B. & Q.
Bessey, C. A., B. Sc. E. E., '99. Sargent & Tundie, Chicago, Ill.
Biggerstaff, C. D., Rock Island R. R. Kansas City.
Bliss, C. V., B. Sc. E. E., '04. J. B. Arnold & Co., Kansas City, Mo.
Brook, I. E., B. Sc. E. E., '03. Chicago, Ill. J. B. Arnold Elect. Co.
Brown, G. F., B. Sc., '04. General Elect. Co., Schenectady, N. Y.
Bates, G. W., B. Sc. C. E., '05. Asst. State Eng., Lincoln, Nebr.
Brockway, Paul S., B. Sc. C. E., '05. Contractors, Brockway & Beardslee, Lincoln, Nebr.
Bally, B. P., '93. Okmulgee, I. T., Electrician.
Baker, L. N., '03. Beatrice, Neb., Beatrice Elect. Co.
Barks, F. S., '02. Omaha, Neb., Mech. Eng. Dept. U. P. R. R.
Barkley, J. A., B. Sc. E. E., '92. Port Elizabeth, Cape Colony, So. Afr., General Manager, Cape Col. Tramway Co.
Bates, G. W., '05. Lincoln, Nebr., Ass't State Engr.
Bedell, C. E., B. Sc. E. E., '00. Pittsburg, Pa. Westinghouse Mfg. Co.
Bellknap, L. J., B. Sc. E. E., '98. Wagner Elect. Co.
Benedict, B. W., B. Sc. M. E., '91. Alliance, Nebr., Ass't Supt. Motive Power, B. & M. R. R.
Benjamin, W. E., B. Sc. E. E., '96. Cheyenne, Wyo., Deputy County Clerk.
Bay, Burt, B. Sc. E. E., '06. Westinghouse Mfg. Co., Pittsburg, Pa.
Bessey, E. A., B. Sc. E. E., '98. Pittsfield, Mass., Expert Electrician, Stanley Elect. Co.
Blzby, J. E., B. Sc. E. E., '01. Denver, Colo. Telephone Dept., Western Elect. Co.

- Bliss, E. F., B. Sc. E. E., '02. Schenectady, N. Y., G. E. Co.
- Bracket, E. E., B. Sc. E. E., '01. Lincoln, Nebr. Lincoln, Traction Co.
- Brooke, W. E., B. Sc. C. E., '92. Minneapolis, Minn. Uni. of M.
- Brooks, G. W., B. Sc. E. E., '02. Schenectady, N. Y. G. E. Co.
- Brown, A., B. Sc., '03. Aurora, Neb.
- Bruce, J. A., B. Sc., '03. U. P. R. & Engr. Dept.
- Buckley, N. E., B. Sc., '03. Curtis, Nebr. B. & M. R. R.
- Buckstaff, Frank, B. Sc., '03. Chicago, Ill.
- Burr, F. D., B. Sc. E. E., '02. Long Distance Power Transmission, Canyon Ferry, Mont.
- Bowlby, H. L., B. Sc. C. E., '05. Instructor in C. E., Seattle, Wash.
- Corr, Ray, B. Sc. M. E. Atlas Engine Works, Indianapolis, Ind.
- Campbell, S. C., B. Sc. M. E., '02. Milwaukee, Wis. Allis-Chalmers Co.
- Charles, E. D., Lincoln, Nebr.
- Chessington, J. B., '04. Lincoln, Nebr. B. & M. Eng. Dept.
- Christenson, W., '00. Utah. Mercur Mining Co.
- Collet, A. J., B. Sc. M. E., '00. Omaha, Nebr. Drafting Dept. U. P. R.R.
- Cortelyou, S. V., B. Sc. C. E., '02. Manila, P. I. U. S. P. S.
- Crane, C. O., B. Sc. E. E. Arnold Power Station Co., Chicago, Ill.
- Crook, Z. E., B. Sc. E. E., '97. Fairbault, Minn. Res. Eng. C., M. & St. P. R.
- Cushman, C. R., B. Sc. E. E., '02. Lincoln, Nebr. Cushman Motor Co.
- Cutshall, L. A., B. Sc. E. E., '05. Chicago, Ill., Automatic Elect. Co.
- Cornell, Clare B., B. Sc. E. E. Musician, Lincoln, Nebr.
- Carter, A. E., B. Sc. C. E., '04. C. E., Columbia Uni. '04 East River Tunnel.
- Chase, L. W., B. Sc. M. E., '04. Lincoln, Nebr. Instructor in Farm Mechanics, Uni. of Nebr.
- Clinton, S. D., B. Sc. C. E., '02. Eng. Dept. Tide Water R. R.
- Davidson, J. B., B. Sc. M. E., '04. Instructor in Farm Mechanics, Ames, Iowa Uni., Ames, Iowa.
- Davis, E. O., B. Sc. C. E., '05. Roadway Department C. B. & Q.
- Dobson, Frank, '02. Lincoln, Nebr. Reclamation Service, U. S. G. S.
- Dempster, J. B., '02 Des Moines, Ia. Dempster Mill Co.
- Doubrava, H. W., B. Sc. E. E., '97. N. Y. City, Wagner Electrical Co.
- Doubt, R. A., B. Sc. E. E., '01. Chicago, Ill., Western Electrical Co.
- Dorman, Fred B., B. Sc. M. E., '01. Foreman of Apprentice Allis-Chalmers Co. West Allis, Wis.
- Eagleson, E. G., B. Sc. C. E., '89. Boise, Idaho, Surveyor General.
- Elson, M. D., Cleveland, Ohio, Western Electrical Co.
- Elson, T. H., '03. Kearney, Nebr., Military School.
- Engel, C. W., B. Sc. C. E., '03. Omaha, Nebr., C. & N. W. R. R.
- Edwards, H. R., B. Sc. E. E., '04. Chicago, Northwestern R. R. Pine, S. D.
- Frans, H. S., E. E., '98. Professor Electrical Eng. Doulter Uni., Boulder, Colorado.
- Farnsworth, G. E., B. Sc., C. E., '04. Tri State Land Co., Scotts Bluff, Iowa.

- Ferguson, O. J., B. Sc. E. E., '03. Prof. Elect. Eng., Union College, Schenectady, New York.
- Forbes, Burt F., A. B., '95. Fort Laramie, Wyo.
- Fritts, Charles, B. Sc. '96. K. C., Mo., Metropolitan Street Ry.
- Geer, Howard, B. Sc. E. E., '05. Los Angeles R. R. Co.
- Gibbs, J. B., B. Sc. E. E., '05. Westinghouse Mfg. Co., Pittsburg, Pa.
- Green, J. A., B. Sc. C. E., '05. Mgr. Culbertson Ditch, Culbertson, Nebr.
- Garringer, A. B. Sc. E. E., '00. N. Y. City. New York Telephone Co.
- Grant, Wm., B. Sc. C. E., '97. Lincoln, Nebr. Office Chief Eng., B. & M.
- Green, J. A., '04. Culbertson, Nebr. Eng. with Standard Beet Sugar Co.
- Green, Wm., '98. Kansas City, Mo. Kansas City Telephone Co.
- Griggs, C. E., E. E., '97. Utah, Mining.
- Gutleben, Dan, B. L., '00. St. Louis, Mich. E. H. Dyer & Co., Sugar Machinery.
- Hagenow, Chas., B. Sc., '00. Lincoln, Nebr. Instructor Math., U. of N.
- Hall, D. C., '98. New York City. Electrician, Navy Yard.
- Harris, R. S., B. Sc. C. E., '04. Omaha, Nebr. Towle Bridge Co.
- Haughton, E. H., B. Sc. E. E., '95. Chicago, Ill. Western Electrical Co.
- Hawksworth, D. W., B. Sc. E. E., '97. Detroit, Mich. Mgr. American Car and Foundry Co.
- Hedge, Verne, A. B., B. Sc. C. E., '03. Lincoln, Nebr. Porter Hedge Abstract Co.
- Henck, C. H., 311 Laurel St., Baton Rouge, La.
- Hess, F. E., B. Sc. C. E., '03. Dallas, Texas, with M. S. Hasey, Bridge Eng.
- Hitchman, J. C., B. Sc. E. E., '98. Tampico, Mex. Mexican Cen. R. R.
- Hoagland, A. L., B. Sc. E. E., '00. Lincoln, Nebr. B. & M. Eng. Dept.
- Holman, W. H., B. Sc. E. E., '04. Lincoln, Nebr. Fellow in Physics Dept. U. of N.
- Holmes, J. C., B. Sc. C. E., '05. Omaha, Nebr.
- Howe, E. D., B. Sc. C. E., '87. Table Rock, Nebr. Farmer.
- Hubbard, R. D., B. Sc. C. E., '99. Reclamation Service U. S. G. S. San Francisco, Cal.
- Hulett, R. E., B. Sc. E. E., '99. Chicago, Ill. Western Electrical Co.
- Hull, A. M., B. Sc. E. E., '02. Fremont, Nebr.
- Hummel, C. M., B. Sc. C. E., '00. Humboldt, Nebr.
- Hunt, F. L., B. Sc. E. E., '02. Schenectady, N. Y. G. E. Co.
- Huntington, L. M., B. Sc. C. E., '02. Culebra, Panama, Canal Zone, Eng. Dept., Panama Canal.
- Hyde, M. A., B. Sc. E. E., '98. Lincoln, Nebr.
- Heaton, R. H., B. Sc. M. E., Fairbanks, Morse Gas Engine Works, Beloit, Wis.
- Hibner, Oldis, B. Sc. E. E., '06. Westinghouse Mfg. Co., Pittsburg, Pa.
- Hurlbut, H. S. G., B. Sc., '01. Hastings College, B. A., '03, and B. Sc. E. E., '05. Uni. of Nebr. Westinghouse Mfg. Co., Pittsburg, Pa.

- Hartzell, Walter, B. Sc. E. E., '05. Westinghouse Mfg. Co., Pittsburg, Pa.
- Holmes, J. C., B. Sc. C. E. Wadell & Hedrick, Kansas City, Mo.
- Hurtz, L. E., B. Sc. E. E., '03. Lincoln, Nebr. City Eng.
- Henry, J. E., B. Sc. C. E. W. Mignery, Contractor and Builder, St. Joseph, Mo.
- Jones, J. C., '96. Westinghouse Co., Salt Lake City, Utah.
- Jeffrey, E. O., B. Sc. E. E., '00. Los Angeles, Cal.
- Jobson, A., Columbia, Mo. Student Uni. of Mo.
- Jorgenson, H. W., B. Sc. C. E., '97. Arizona, Mining Eng.
- Joy, G. A., '01. Chicago, Ill. Supt. Kellog Switchboard and Supply Co.
- Kemmish, N. A., B. Sc. M. E., '04. Lincoln, Nebr. Lincoln Traction Co.
- Kinton, W. G., '98. Chicago, Ill. Chicago Telephone Co.
- Koch, A. W. F., B. Sc. C. E., '05. Lincoln, Nebr. Eng. Dept., B. & M.
- Korsmeyer, L., B. Sc. C. E., '00. Lincoln, Nebr. Korsmeyer Plumbing Co.
- Krasny, Emil, B. Sc. E. E., '03. Humboldt, Nebr.
- Kallasch, W. M., '02.
- Kandall, H. C., B. Sc. E. E., '02. Lincoln, Nebr.
- Kruse, A. N., B. Sc. E. E., '03. New York Office of Western Elect. Co. New York.
- Kuhns, J. H., '96. Professor of Elect. Eng. in Japan.
- Koch, A. W. F., B. Sc. C. E. C. B. & Q. R. R., Lincoln, Nebr.
- Langer, J. F., B. Sc. E. E., '00. New York City. Elect. Insp. U. S. Navy Yard.
- Langley, R. R., Omaha, Nebr. Home Correction School.
- Larson, C. H., B. Sc. C. E., '02.
- Lawler, J. C., '02. Colorado Springs, Colo.
- Lewis, O. E., B. C. E., '84. Falls City, Nebr.
- Leibman, M. N., B. Sc. E. E., '00. New York City. Manager Foote-Pierson Co.
- Lord, H. S., B. A., '93. Butte, Montana, C. E.
- Lyon, Geo. J., B. Sc., '99. Colorado Springs, Colo. Prof. C. E. Colorado College.
- Maghee, M. M., B. E. E., '92. Rawlins, Wyo. Electrician.
- Manley, F. A., B. C. E., '89. Rock Springs, Wyo. Chief Eng. U. P. Coal Co.
- Mansfield, R. J., B. Sc. M. E., '04. Wisner, Nebr.
- McReynolds, R. H., B. Sc. E. E., '04. Lincoln, Nebr. Electrician, U. of N.
- Miller, A. A., B. Sc. E. E., '98. Seattle, Wash. Westinghouse Exp. Office.
- Morse, P. A., B. Sc. E. E., '93. 3242 Cal. ave., St. Louis, Mo. Western Electric Co.
- Mueller, R. S., B. Sc. E. E., '98. Chicago, Ill. Kellogg Switchboard & Supply Co.
- Mundorf, W. M., B. Sc. E. E., '02. Omaha, Nebr. Paxton & Vierling Works.
- Mills, David, B. Sc. M. E., '05. C. B. & Q. R. R., Havelock, Nebr.

- Miller, J. W., B. Sc. C. E. C. & N. W. R. R. Deadwood, S. D.
- Meyer, F. L., B. Sc. E. E., '97. Roebling Sons Co., Trenton, N. J.
- McDowell, C. C., B. Sc. E. E., '05. General Elect. Mfg. Co., Schenectady, N. Y.
- Main, A. E., B. Sc. E. E., '03. Hot Springs, Ark.
- McCrosky, J. W., B. Sc. '91. London, Eng., Manager of J. G. White & Co. Ltd., Contractors.
- McGeachin, W. R., B. Sc. E. E., '93. Manilla, P. I. Supt. of Manilla Elect. Light Plant.
- Newton, B. A., B. Sc. C. E., '04. Lincoln, Nebr. B. & M. Eng. Dept.
- Noyes, H. B., B. Sc. E. E., '98. Omaha, Nebr. Motive Power St. R. R.
- Noyes, R. E., B. Sc. E. E., '04. Schenectady, N. Y. G. E. Co.
- Oliver, R. H., B. Sc. E. E., '03. Arnold Electric Power Sta. Co., Chicago, Ill.
- Orton, C. S., B. Sc. M. E., '02. Milwaukee, Wis. Allis Chalmers Co.
- Pearson, C. A., '01. Omaha, Nebr. Inst'r Drawing, High School.
- Pepperburg, A. J., '02. Navy Yard, New York City.
- Podlesack, H. J., B. Sc., '94. Chicago, Ill. Electrician.
- Podlesack, T. S., B. Sc., '96. Chicago, Ill. Electrician.
- Pollard, N. L., B. Sc. E. E., '96. Mexico City, Mex., Mexican Central Electrical Co.
- Pool, C. H., '00. New York City. New York Telephone Co.
- Porter, E. Y., B. Sc. E. E., '96. Newark, N. J. Moore Elect. Co.
- Posqisil, L. J., B. Sc. M. E., '03. Seattle, Wash. Draftsman.
- Porterfield, J. R., B. C. E., '92. Boise, Idaho. C. E.
- Randal, K. C., B. Sc., '97. Edgewood, Penn. Westinghouse Co.
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A BIT OF FRIENDLY ADVICE.

Chancellor E. B. Andrews.

Two points should be emphasized by intending engineers both of which they often neglect as of little consequence.

The first is facility and correctness in writing English. To think clearly and have something to say is of course the main thing, but to be able to say and particularly to write things in clear, concise, elegant English is about equally important. The clear thought may merely evidence a good mechanic; the other indicates original and constructive mentality. Engineers often have to draft specifications, contracts, bids. The ability to select instantly the right bolt or screw is often of less service to an active engineer than quick word discrimination and the power of lucid, precise statement.

To this mastery of English an ambitious engineer should add a practical knowledge of French or of German, preferably of both. In one or the other of these languages are expounded the newest and best engineering and mechanical discoveries made abroad. The scientific engineer should be able to read these accounts at first-hand, not waiting the slow process of translation. The University offers splendid opportunity for learning both French and German. Get the drudgery of these languages off your hands with your other preparatory work, then perfect yourself in them by persistent reading. Never use translations when you can obtain originals. The exact sense of a presentation in a foreign language is nearly always impaired by translation.

The second point deserving stress is the resolution and preparation permanently to keep up your distinctly technical outfit, especially your mathematical knowledge. Your great temptation after beginning work will be to rely more and more on "rule of thumb." Do not yield: do not become a slave to rule of thumb. Very often you will find yourself in situations where good work will require you to reach straight back to your best theoretical knowledge. With this reserve outfit ready for use you will score richly over your naturally clever but uneducated rival, trained by apprentice methods but lacking in theory.

Careful attention to details should of course be your habit. All your training teaches you the value of this. Not so clearly will you see the value of non-technical subjects. Do not be an engineer and nothing more. Be also a man, an observer, a reader, a thinker. Place your earliest ideal high. See how much you can gain from your University course rather than how little you can do and still win your sheepskin. You can graduate without understanding any tongue but your own and with little facility in that; but how much better equipped, how much surer of large success, the man who has an ample, round-about mental development.

Remember ever the words of R. H. Stoddard: "The more we know of any one ground of knowledge, the farther we see into the general domain of intellect."

SALES ENGINEERING.

A. A. Miller, (Sales Engr.) Westinghouse Electric & Mfg. Co., Seattle, Wash.

Certain lines of business carried on today by large financial interests, have been built upon the practical application of what was largely theory only a dozen or fifteen years ago, business still depending to a remarkable degree upon the brain power and inventive skill of technical men constituting its engineering force, men who are constantly devising either new applications for comparatively old ideas, or who are bringing out something entirely new.

In the electrical machinery manufacturing industry there are today in the United States, three or four very large corporations, among which there exists the most lively competition, each one apparently trying to out do its rivals, and employing every reasonable means to accomplish this end.

Trusts of all classes and varieties are the common subject of newspaper gossip—yet it is rarely stated that there is in existence an electric manufacturing combination of threatening magnitude. The facts of the case are that no such combination does exist, actual competition being so deeply rooted as to make it difficult to imagine how conditions in this respect might be worse.

Each of these manufacturing companies has established for itself a reputation that is carefully guarded in the spirit of friendly rivalry in furthering the science of applied electricity and it would be very wrong to neglect to say, for the purpose of increasing dividends, but it is true nevertheless that both of these factors have combined to force electrical development along at a truly wonderful rate, more so than any other combination of influences.

The earning of dollars is an evil habit to which all of us are more or less thoroughly addicted, but since our civilization is thus strongly tainted, what individual or what corporation can point a scolding finger at the other for employing as before mentioned every reasonable means of increasing its own efficiency and earning capacity? Shop methods are carefully scrutinized, designs are economically made, and every effort of the entire production department is bent toward bringing out a class of apparatus thoroughly reliable and of a very decided order of excellence, at a cost that will allow it to more readily sell when placed on the market. It is then up to the sales department to take

the matter in hand and from that time until the last of the deferred payments is made the salesman is busy negotiating and settling up business.

The sales organization of a manufacturing company of any sort whatsoever is truly the life of that company and anything that strengthens that organization is of very great benefit. It is just here in the order of events that the sales engineer really enters, and nowadays plays a very considerable part in the real life of these corporations.

Before taking up his immediate work, it is proper to look at the process of manufacture through which he must go before approaching the condition of finished product, which latter is never attained, as he is not made of iron, and steel and copper, but retains all the ingredients of ordinary human weakness.

During the last six or eight years particularly, there has been a decided effort of sales managers to secure for their departments a set of men whose training and experience has been along technical lines, men who are either graduates of technical schools and colleges or are strong in the field of every day practice. The college man is most largely in evidence and in the end generally reaches higher levels than the other class mentioned, but only after some years of close application to the business of manufacturing machinery. This he learns by taking advantage of the very excellent engineering apprenticeship courses now offered in several large electric works, and being thus permitted to investigate in a very practical way, many of the ramifications of the business, accumulates by the simple process of absorption a vast fund of information.

These engineering courses, for a time were tried as an experiment, were variously modified from year to year, and were finally so thoroughly satisfactory to all concerned, as to lead to the plan being adopted unconditionally as the most successful that had been tried. Particularly in one electric company, young men are selected from among the apprentices for recruiting nearly every department of the works and also of the district offices. Therefore a man's opportunities are ample and his success measured truly by his aptitudes and limitations, for it is a fact that the electrical industry has grown so enormously and at such a rapid rate that an actual scarcity of no small proportions exists when it comes to finding men properly trained and possessing personal energy sufficient to send them along at reasonable speed, when placed in positions requiring a positive degree of good intelligence and perseverance.

The course covers about two years at the works, in the shop, testing departments, engineering offices, and correspondence departments. After this gauntlet has been run, it is not difficult to recognize along what particular line of action the apprentice

is best fitted to move, whether as an engineer pure and simple, or as one to whom the technical side of any given situation appeals strongly, but does not overshadow the far reaching commercial aspect. These two factors used conjunctively are the warp and woof of sales engineering which covers both salesmanship and engineering, a combination in which the efforts of the engineer are all bent toward assisting the salesman. The salesman of the combination must employ good engineering for several reasons:

First, because if he *does not*, his competitor *will*.

Second, because only those recommendations based on sound judgment and good engineering principles will give *good* and not *indifferent* results.

Third, because poor engineering and poor recommendations reap a most prolific harvest of trouble both for the manufacturer and the user, resulting in a situation often very difficult to settle financially and quite naturally an absolute loss of any further opportunities to do business with the same buyer again.

Some eighty years ago, Tredgold gave a definition of engineering that has never been improved upon. It is the art of directing the great sources of power in nature to the use and convenience of man. This is the broadest interpretation of the term. More narrowly considered an engineer has been defined as a man who can do well for one dollar what any man can do somehow for ten dollars, and as applied to sales work, the engineer's instincts so guide and direct his forces in competitive work as to result in success often where failure would otherwise attend.

It would be very incorrect to state that not much engineering ability is required to sell incandescent lamps, for example, but when the subject is seriously considered, a host of technicalities reveal themselves, such that it is about as much as one man cares to do, and do well.

When the sale of a small motor or generator is negotiated, a few judicious questions will usually bring out sufficient information from the buyer as to result in his getting what he needs. It is unsafe to proceed on the theory that a buyer knows what he wants unless that buyer has been educated by long experience. He is usually ready to receive suggestions, which when applied, gives him an up-to-date outfit, whatever it may be. In the case of an isolated system of small proportions, the application of apparatus that has been thoroughly standardized will usually solve the problem, although in some cases, apparatus of the most special sort is required to fit a set of conditions not to be duplicated elsewhere in a long time.

Power transmission systems come next in order of importance, ranging from a hundred kilowatts or so in size to several

thousand, involving transmission lines some miles in length. In a country or section where water power predominates, as in the Pacific Northwest, each development is different from every other so there is not at hand a set of rules to follow, but each case must be worked out by itself, and the application of electrical apparatus made to fit local conditions.

It is customary at the present time, and has been for several years, for the electric manufacturing companies to do gratis a large amount of engineering work which should be done by consulting engineers. The keenness of competition however has made the manufacturers willing to lend engineering aid in the development of new power and railway systems. Naturally the sales department comes in touch with new projects before the factory hears of them, so it is one of the duties of the sales engineer to get up such preliminary reports as are required for sending to bankers and financial circles and floating the project on the money market. If it is a power proposition, this report must cover the amount of power available, cost of development, distance from and the extent of the market, otherwise probable load to be carried, the indicated earning capacity and such other pertinent factors as appeal to and are required by monied men in looking up investments.

A railway project is the most difficult of all to handle, as it involves so many variable and seemingly indeterminate elements. Reports on matters of this class need a great deal of care and attention. It is seldom the case that the same set of financial men will become equally interested in both power and railway projects; usually they confine their attention to one or the other and do not overlap.

Economically the position of the sales engineer is that of a producer. He enjoys numerous benefits aside from the compensation afforded. Among these are:

First, the opportunity to keep in touch closely with the real and prospective development (in his line) of a few states particularly and of the entire country in general

Second, the opportunity to keep tolerably close to engineering work in general and perhaps one or more of its branches in particular.

Third, the value of getting advance information covering a new system or a new phase of an old system, thus keeping perhaps a little ahead of the times instead of abreast of them.

The term "sales engineer" is one of comparatively new coinage, but as it describes very well a class of services likewise of tender years, its use will no doubt grow until its true meaning is thoroughly understood. It has been the writer's intention to explain somewhat in detail just the manner of man involved and his work.

THE FLOW OF NEBRASKA STREAMS AND ITS RELATION TO RAINFALL.

By J. C. Stevens, Hydrographer, U. S. Geological Survey.

To guess at the tithe and multiply by ten is more accurate than guessing at the final result, is a doctrine never preached but not infrequently practiced. An engineer who would not think of guessing at the mean annual flow of a stream, will guess at the yield in inches of depth, or the percentage of rainfall appearing as run-off, with reckless abandon multiply by the drainage area, divide by the number of days in the year times .0372 and tell the mean discharge to a nicety.

No small amount of study has been given to the subject of rainfall, volumes have been written about it, and many liberties have been taken with the records when applying them to the determination of stream flow. For years engineers and scientists have been endeavoring to determine a general relation between these quantities. The net results so far obtained may be briefly stated in relative terms. A heavy rainfall produces a large run-off, in dry years the run-off is less than in wet years. "More" and "less" are just about as concrete terms as one dare apply to this relation.

Observe the exact nicety with which Mr. Thomas Russell, in Rainfall and River Outflow in the Mississippi Valley, Ann. Report Chief Signal Officer for the year 1889, has developed formulas for that valley. His formula for the Upper and Middle Missouri is:

$O = 0.12 + 0.98 R - 0.93 R (0.91e - 0.220e^2 + 0.009e^3)$ where
O = outflow or run-off in cubic miles.

R = rainfall for the same period in cubic miles.

e = quantity of water required to saturate the air.

For October 1881 this formula gives an outflow of 4.9 cubic miles, while the observed run-off was 1.6 cubic miles. Only an error of two hundred and six per cent! As if the discharge of the Missouri River at Omaha is dependent in any manner upon the simultaneous rainfall in Montana. George W. Rafter* strenuously objects to the term "percentage of rainfall or anything approximating to it," and yet in the next paragraph we see the statement "Usually about 0.75 of 0.85 of the total rainfall of this period appears as run-off in the stream." What's in a name? He gives a diagrammatic relation between the annual precipitation and run-off from a number of watersheds in the eastern part of the United States.

For the Hudson River the observed values for the consecutive years of 1889 and 1900 show a variation of 50% from that given by the curve, for which he has developed the equation:

$$P^2 = 84.5 R$$

where P = annual precipitation

R = annual rainfall.

He prefaces his remarks by the statement "In computing the run-off of various streams, small discrepancies will continually appear, and when such do not exceed 1 to 2 inches they are outside the limits of discussion." Two inches is four times the annual run-off from the drainage basin of the Republican River, and practically excludes all streams of the western plains from the discussion. Yet many instances can be cited where engineers have applied the discussions and formulas developed for streams in the eastern humid part of the United States to streams in the arid West, and with this flimsy foundation built works of considerable magnitude, only to find themselves outwitted by nature.

*It is therefore high time that some actual facts and figures were given and the marked individuality of the streams of the plains in this regard forcibly pointed out.

Negative information is often the most valuable, and here we have plenty.

USES OF STREAM FLOW DATA.

It will be necessary to first give a brief review of the uses to which stream discharges are put, and the quantities to be determined for these several usages. In general all demands for discharge data can be classified under one or more of the headings, Irrigation, Water Power, or Municipal Water Supply.

Irrigation generally demands the most complete data, for if a stream does not furnish sufficient water for the draft upon it during the irrigation season, storage is usually resorted to where such is practicable. In the event of a stream being required to furnish its entire annual yield in the most economical manner, it is necessary to know the mean daily discharge for every day in the year, for a number of years. With such records at hand, the remaining quantities, namely, minimum flow and its duration, floods and their duration, excesses over demand available for storage and their distribution can be determined. The flow of a stream and the demands upon it can be mapped as completely and concisely as a township of land.

Water Power. It is seldom feasible to resort to extensive artificial storage in order to render a stream suitable for water power development. In general the capacity of a hydraulic plant is limited to the minimum flow of the stream, and

where such minimum is insufficient for the required load it is usually cheaper to have an auxilliary steam plant to tide over a low water period than to resort to artificial storage. The data therefore required for water power is (1) the minimum discharge and its duration; (2) the flood discharge in order that suitable spillway capacities in diversion dams can be provided as well as to provide protection for power house, flumes, etc., and for the proper design of headgates. In general therefore, gauging stations maintained during low water periods, together with occasional measurements of flood discharges will furnish sufficient data for water power development.

Municipal Water Supply. The actual quantity of water required for municipal purposes is relatively small compared with the uses before mentioned, and where surface waters are used for this purpose the only requisite is that the minimum discharge shall not fall below the maximum rate of consumption, while a knowledge of the flood discharge is valuable only for the proper design of diversion works. On the basis of a water consumption at the rate of 100 gallons per day per capita, 10 cubic feet per second will supply a city with a population of 65,000 inhabitants, while the flow of the Niobrara River in Nebraska would supply Greater New York with an abundance of water without the elaborate system of storage now in existence.

THE RAINFALL-RUN-OFF RELATION.

In an arid country, since a knowledge of the distribution and duration of the various rates of stream discharges is a requisite for its proper development, it is hardly necessary to say that no method can compare in reliability with that of actual systematic stream measurements, extending over a period of several years. It will also be evident after a little investigation that records of rainfall are entirely inadequate for this purpose. It is however frequently necessary to make some estimate of the quantity of water yielded by a particular drainage basin, on which no systematic records of stream flow have been kept. In such cases it is almost useless to attempt the determination of the time distribution of the various rates of discharge, but efforts must be confined to that of discovering either the mean annual yield, the quantity supplied year by year, or that supplied during distinct climatological periods of the year. This follows from the law of averages that individuality is sacrificed for the determination of class likeness. Hence the longer the period for which the total yield is required the more reliable will our estimate be.

In order to substantiate the foregoing it is only necessary to consider some of the natural conditions affecting the relation between the discharge of a stream and the precipitation on its

watershed. The causes of rainfall are too complex and too little understood to be discussed here. All authorities are agreed that "in order to produce rain the temperature of the air must be suddenly cooled below the dew point," which however cannot be given as a cause of rainfall, but follows directly from our definition of "rainfall" and "dew-point." Whatever its cause it is sufficient for our purpose to know that rain does fall and that the United States Weather Bureau is chiefly concerned in the determination of its amount and distribution. Since all flowing water must at some recent period have passed through the state of precipitation, it follows that there must be some definite relation between rainfall and run-off, and the fact that we cannot determine this relation is merely proof that we cannot take into account all the conditions influencing this relation. These conditions are best illustrated by concrete examples. Let us take first the simplest possible case, that of an impervious roof of known area and known slope from which the water is conducted by cave troughs over a weir to a reservoir. Assume also a rain guage in place to determine the precipitation. Disregarding the effect of evaporation, the total quantity falling on the roof in any period of time will later appear in the reservoir and should be the depth times horizontal projection of the area. The determination of the *rate* of run-off is a different proposition, since to find this we must know the *rate* of rainfall, then from observation of the rate of flow over the weir and the storage capacity of conduits to the weir and the rate at which water was stored therein, we could determine the relation between the rate of rainfall and the rate of run-off for that particular roof, at that particular angle, with that particular system of conducting the water therefrom. The mean rate is of course the total quantity precipitated, divided by the time, but that is merely expressing quantity in another unit. The maximum rate would be indeterminate without elaborate preparations.

If now instead of the smooth impervious roof we take an area of sod, soil, sand, and gravel of unknown thickness. The quantitative determination could even in this case be made, but we would have to take into account the previous saturated condition of the material and the evaporation since our observations would have to be extended over a much longer period of time to attain any degree of accuracy. The maximum rate of run-off could be determined for only that particular condition of saturation existing previous to the rainfall.

When we consider that the conditions in nature are far more complicated than we are able to illustrate by a simple case like the above, that the precipitation occurs under all climatic conditions from torrential "cloud bursts" of a few minutes duration

to gentle showers lasting for weeks, from driving blizzards on frozen ground to fleecy snows that melt into slush during the day and freeze at night; when we consider that our records of precipitation at best are only approximations, with rarely any attempt at rate determination, and that frequently our stream flow data are just as inaccurate and incomplete, who can blame the engineer for guessing at the tithe and multiplying by ten?

RUN-OFF FORMULAS.

Bearing in mind then that a determination of the rate of stream discharge from records of rainfall is practically out of the question, and that any quantitative analysis is only the roughest approximation, an examination of some of the formulas now in use purporting to express this relation will be of interest.

Formulas for Maximum Discharge. Mr. J. T. Fanning proposes the formula

$$D=200 M^{5/6}$$

where D is the discharge in second feet and M the drainage area in square miles. This relation was determined from plotting the flood discharge of some American streams. No mention is made of the kind or size of drainage areas to which it is applicable.

The Ryves formula is:

$$D=C M^{2/3}$$

and Colonel Dickens proposes:

$$D=C M^{3/4}$$

In the last two C is a sliding coefficient, depending upon the natural characteristics of the drainage basin. For the Dickens' formula, C has the following values for flat countries; where rainfall of from 3.5 to 4 inches in twenty-four hours may occur, 200; for a maximum rainfall of 6 inches, 300; the Ryves coefficient varies between 400 and 500 in flat countries.

Let us see what such formulas for Nebraska streams will give. Colonel Dickens' formula is perhaps the most conservative, and using a coefficient of 200 we find the following maximum rates of discharge:

Elkhorn River at mouth, 5980 square miles, 139,000 sec. ft.

Loup River at mouth, 13540 square miles, 250,000 sec. ft.

Republican River at Superior, 22,350 sq. mi. 366,000 sec. ft.

I predict that if ever such quantities of water should come down these rivers, a new map of the state will be required at once. The maximum recorded discharges are, for the Elkhorn 9,600, Loup, 26,000, Republican 25,000.

But it will be contended that these formulas were never intended to apply to such large areas in arid countries. The Salt River of Arizona with steep bare slopes has a drainage area of 12,260 square miles at Phoenix. The maximum observed dis-

charge in 1891 was about 300,000 second feet, which would fall very near Colonel Dickens' curve.

Formulas for Minimum Discharge. When we realize that the Platte and Republican Rivers go entirely dry and that the Niobrara and Loup Rivers have a minimum flow of about one-tenth of a second foot per square mile of drainage area, under practically the same conditions of rainfall, the absurdity of attempting to apply any formula for minimum rate determination is at once obvious.

DETERMINATION OF MEAN ANNUAL RUN-OFF.

A quantitative determination of the total yield of a watershed during distinct climatological periods of time can often be approximated with some show of reason, provided we use average or normal values for such periods. I will say further that the determination of stream flow from rainfall records must legitimately be limited to this problem on account of the large debits and credits at the beginning and end of short periods of time. To illustrate: the percentage of rainfall appearing as run-off in a single month will depend among other things upon the saturated condition of the soil at the beginning of the month. If the ground water is depleted, a large part of the precipitation will go to augment the ground storage, if on the other hand ground water is above the normal quantity, a much larger percentage of precipitation will run off from the watershed. Again if a heavy rainfall appears at the end of the month the total run-off for that month might be very low and the rainfall comparatively high, while the following month the conditions would be reversed. It is therefore necessary to consider longer periods of time, and for convenience the year is considered in two seasons designated as the Open Season, from April to October, inclusive, and the Closed Season from November to March, inclusive. In the plains of the Middle West, on account of uncertain ice conditions, it is impossible without great expense to obtain stream flow data during the Closed Season, hence the discharge of Nebraska streams is known only for the Open Season. In 1897 daily discharges were tabulated during the Closed Season for Nebraska stations from rating curves developed during the Open Season, but they are not only incorrect but grossly misleading. I have seen the Platte River frozen practically solid to the bed, the position of the water on the gauge which if applied to the Open Season rating curve would indicate a discharge of four or five thousand second feet, when as a matter of fact there was less than a hundred trickling along under the ice.

Spring Floods on the Platte River. It is popularly believed that the magnitude of the periodic spring floods on the Platte River depend entirely upon the quantity of snowfall on its head-

waters during the preceding winter, but it appears that this is only partially true, that is to say, there are so many other influences such as the previous conditions of the soil saturation, and the manner in which the winter snows are melted that the relation between these quantities is not at once apparent. In table 1 the total run-off as measured at North Platte for the flood period of each year, April to July inclusive, is compared with the total precipitation on the drainage basin above that point, for the preceding winter season, November to March inclusive.

TABLE 1.

Relation of Winter Snowfall on Headwaters of North Platte River to total Run-off During the Following Spring Flood Period at No. Platte, Neb.

| | 1895 1896 | 1896 1897 | 1897 1898 | 1898 1899 | 1899 1900 | 1900 1901 | 1901 1902 | 1902 1903 | 1903 1904 | 1904 1905 | Av. |
|-------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|------|
| PRECIPITATION NOV. TO MAR. | 3.06 | 3.24 | 2.73 | 5.00 | 1.59 | 2.69 | 3.24 | 3.59 | 1.46 | 2.28 | 2.89 |
| DEPARTURE FROM AVERAGE | +.17 | +.35 | -.16 | +2.11 | -1.30 | -.20 | +.35 | +.70 | +1.43 | -.61 | .... |
| RUN OFF APRIL AND JULY | .57 | 1.46 | .66 | 1.62 | 1.05 | .84 | .61 | .74 | .86 | 1.38 | .98 |
| DEPARTURE FROM AVERAGE | -.41 | +.48 | -.32 | +.64 | +.07 | -.14 | -.37 | -.24 | -.12 | +.40 | .... |

It will be seen that in 1896 the run-off was only about half the average for the ten years following, although the precipitation was considerably above the average. This is explained by the fact that during the three preceding years, 1893 to 1895 inclusive, the precipitation throughout Nebraska and neighboring states was far below the normal, and the ground water was greatly depleted so that the larger precipitation in 1896 was used up in restoring the ground water to more nearly its normal conditions and therefore did not appear in the stream. The maximum precipitation and run-off occurred simultaneously in 1898 and 1899, which no doubt resulted in an abnormal amount of ground storage so that during the following season in spite of the fact that the precipitation was only about half the average, the run-off was above the normal. The excessive floods which occurred in the summer of 1905 (see Table X) were evidently not solely caused by snowfall in the mountains, as the precipitation for the preceding winter was far below the normal.

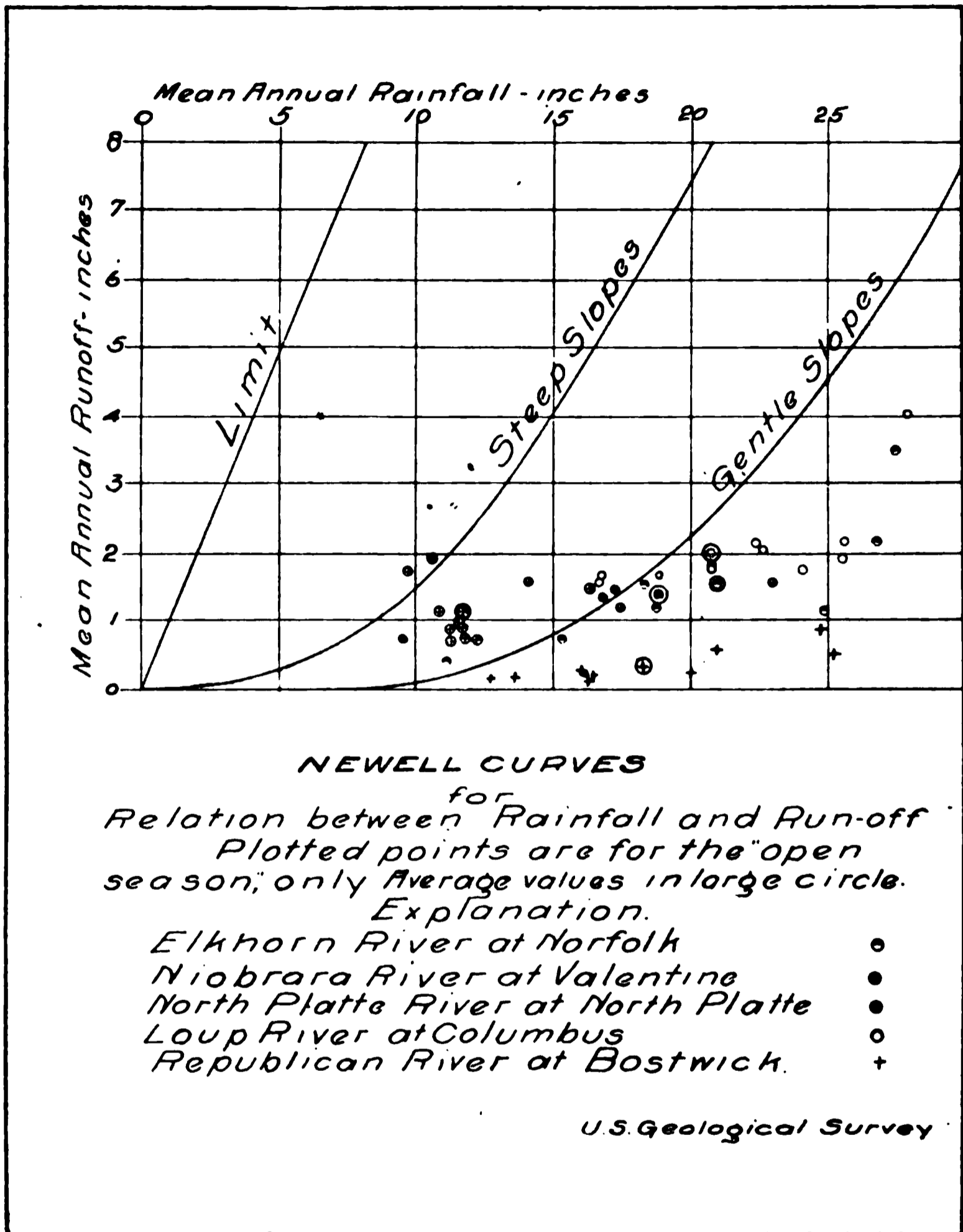


Fig. 1.

Returning to the subject of annual run-off and its relation to annual precipitation, Mr. F. H. Newell, Chief Engineer U. S. Reclamation Service, about 1898 prepared a set of curves from all data then available which express perhaps the best known relation between these quantities. These curves now known as the "Newell Curves," are reproduced in figure 1, on which are also plotted the run-off in inches as measured at the U. S. Geological Survey stations for the Elkhorn River at Norfolk, the Niobrara River at Valentine, the Loup River at Columbus, the North

Platte River at North Platte and the Republican River at Bostwick, with the corresponding precipitation in inches on their drainage basins, taken from records of the U. S. Weather Bureau. It is true that the run-off here plotted is only for the Open Season, but the precipitation for the same period is used. If we had complete yearly records of run-off and had used corresponding yearly values of precipitation the relative position of the points would not be materially altered as each would then appear above and to the right of the position now occupied. Moreover, the amount they would appear to the right of their present position would be small compared with the distance they would be moved upward, for the reason that the precipitation during the winter months is a very small proportion of the annual amounts, (see Fig. 2), but this difference does not exist for the run-off factor. In other words the percentage of precipitation appearing as run-off is much greater in winter than during the remainder of the year; so that if we had complete records, it is believed that the *mean annual values* for the Loup and Niobrara Rivers would not fall far short of the curve for gentle slopes. The Republican and North Platte Rivers are hopelessly incongruous.

AVAILABLE DATA.

As a guide to the quantitative determination of run-off for streams other than those investigated by the U. S. Geological Survey, existing under similar climatic conditions, there is presented herewith all the available data collected on Nebraska streams, which are of a sufficiently reliable nature to justify their use in this connection.

Units. In the following tables and in the previous discussion, run-off is expressed in inches of depth, and is the depth to which the total quantity of water passing the gauging station would have covered a plane surface equal in extent to the drainage area of the stream above that point. In this manner the flow of a stream becomes at once comparable with rainfall which is measured in inches of depth.

It is unfortunate that the term "run-off" has been applied to so many different units. In this discussion it has, and always should be, used to denote a total quantity, and not a rate of flow. It may be expressed as depth in inches over the drainage area or in acre feet. Rate of flow is properly denoted by the term "discharge" and should be expressed in cubic feet per second—or for brevity, second-feet—although usage has sanctioned the term "million gallons per twenty-four hours" in connection with municipal water supply. For more complete description of the catchment areas of the streams, for which data are presented herewith, the reader is referred to the 19th and subsequent Annual Reports of the U. S. Geological Survey, Pt. 4.

Fig. 2.

Descriptions of Drainage Basins. The Elkhorn River is wholly in Nebraska. Its area is rolling, broken in places, and largely cultivated or grass grown. It heads in the sand hills of Rock County.

The Niobrara and Loup River drainage areas are similar. Consisting largely of rolling sand hills; they are given over to range land, or cultivated in small tracts where the soil is firm.

The sand areas are the controlling features of these streams, since the precipitation thereon is absorbed by the sand and gradually fed to the stream in the form of springs. To this fact alone is due the remarkable constancy of flow observed on both rivers, as their drainage areas act in themselves as conserving reservoirs.

The North Platte River partakes of the nature of a mountain stream and a river of the plains. It rises in Northern Colorado, drains a large mountainous area in Wyoming, and traverses Nebraska on a bed of sand. It receives no large tributaries after leaving Wyoming. Its drainage area in Nebraska is rolling range land with cultivated valleys.

The Republican River is not unlike the North Platte except that it has not the mountainous headwaters. In Colorado its drainage basin is table land broken by canyons and gullies and interspersed with low hills and rocky scab land. In Nebraska it drains a considerable area of sand hills, which however is only a small portion of the entire catchment basin.

Explanation of Tables. Tables II to V give the total monthly precipitation on the drainage basins of the rivers mentioned above for the ten years 1895 to 1905 inclusive, together with the normals compiled from records of a much longer duration. Each figure in the tables is a mean value obtained from a number of well distributed stations throughout the basin.

The precipitation in Nebraska decreases at the rate of about 4 1-2 inches per hundred miles as we go westward. It has therefore been necessary to avoid giving too much weight to the eastern portions of a drainage basin, since available records predominate here to the exclusion of the Western part. that is to say, the rainfall should be weighted by the area served by that station, evidently an indeterminate problem, or care taken to choose stations that serve equal areas. Where records for any one station were incomplete the rainfall for an adjoining station has been used.

Tables VII to XI give the run-off in inches as measured at the gauging stations of the U. S. Geological Survey, together with the monthly rainfall for each month covered by the run-off records. The run-off is also expressed in percentages of the rainfall for the same period of time. The records for individual months are of little value except to show how great the variation is. At the end of each table will be found mean values for each month, and a summary of total amounts for the season. In these we do not find such wide variation, but the relation is yet anything but apparent. Note the remarkably low percentage for the Republican River.

In order to show more concisely the relation, the mean and total values at the end of each table have been plotted and are presented in figures 2 and 3.

Figure 2 gives the monthly precipitation for the entire normal year, and directly below the monthly run-off for the *average* season, records not being of long enough standing to establish *normal* values.

4

10

20

30

40

Fig. 3.

Figure 3 gives the total seasonal values of the rainfall and run-off. The same scales have been used throughout in order to show the relation and characteristics of each stream.

CONCLUSIONS.

The streams of the Western plains have a marked individuality in respect to the rainfall-run-off relation, compared with streams in other portions of the United States, and formulas elsewhere applicable are wholly inadequate and may lead to grossest errors.

Formulas for maximum and minimum discharge are worthless.

The magnitude of spring floods in the Platte River is not dependent upon the snowfall in Wyoming during the preceding winter.

The run-off during the winter months cannot be arrived at through the use of precipitation records. Considerable time was spent in an endeavor to determine rational values for winter flow, from winter records of precipitation. It is undoubtedly true that a much larger percentage of the precipitation appears as run-off in the winter than during the remainder of the year, but just what the ratio of the percentages of rainfall for the two periods is, is wholly indeterminate.

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TABLE NO. II.

Precipitation in Drainage Basin of Elkhorn River, above Norfolk, Nebraska.
Drainage Area 2470 sq. mi.

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Annual |
|--------|------|------|------|------|------|------|------|------|-------|------|------|------|--------|
| Normal | .67 | .70 | 1.43 | 3.12 | 9.73 | 9.08 | 7.43 | 6.51 | 1.12 | 1.09 | .51 | .61 | 19.20 |
| 1885 | .59 | .45 | 2.14 | 3.99 | 1.94 | 3.78 | 1.11 | .71 | .78 | .10 | .80 | .12 | 15.43 |
| 1886 | .58 | .34 | 1.59 | 2.44 | 1.45 | 3.63 | 2.80 | .69 | .25 | .86 | 1.89 | .20 | 18.72 |
| 1887 | 1.64 | .70 | 1.58 | 1.51 | 1.85 | 1.12 | 2.33 | .80 | .37 | 1.17 | 1.23 | 1.46 | 19.98 |
| 1888 | 1.01 | .56 | .85 | 1.08 | 1.40 | 1.63 | 2.98 | 1.57 | .85 | .24 | .54 | .48 | 17.65 |
| 1889 | .42 | .56 | 1.06 | 1.00 | 1.60 | 1.43 | 1.11 | 1.32 | .70 | .25 | .94 | .26 | 16.76 |
| 1890 | .09 | 1.10 | .89 | .41 | 2.49 | 1.42 | 5.74 | 3.12 | .65 | 1.52 | 1.45 | 1.61 | 22.12 |
| 1891 | .03 | 1.36 | 1.66 | 1.45 | 1.32 | .70 | 1.43 | 1.44 | 3.38 | .31 | .03 | .95 | 22.43 |
| 1892 | .46 | 1.22 | 1.84 | 1.08 | 2.60 | 3.73 | 1.26 | 1.77 | 1.34 | .80 | .41 | .55 | 19.86 |
| 1893 | .50 | 1.31 | .81 | 1.72 | 2.27 | 1.66 | 5.74 | 1.31 | .52 | .63 | .08 | .23 | 20.29 |
| 1894 | .60 | .24 | .28 | .70 | 2.68 | 5.08 | 3.00 | 2.55 | 1.93 | 1.28 | .02 | .23 | 18.64 |
| 1895 | 1.03 | .26 | 1.09 | 2.90 | 5.24 | 5.79 | 4.51 | 1.69 | .97 | 1.16 | .60 | .16 | 25.30 |

TABLE NO. IV.

Precipitation in Drainage Basin of Loup River above Columbus, Nebraska.
Drainage Area 13,540 sq. mi.

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Annual |
|--------|------|------|------|------|------|------|------|------|-------|------|------|------|--------|
| Normal | .48 | .58 | 1.09 | 2.88 | 3.18 | 4.16 | 5.92 | 3.61 | 3.03 | 1.30 | .48 | .47 | 32.70 |
| 1885 | .18 | .85 | .79 | 2.06 | 4.48 | 4.76 | .98 | 2.40 | 1.81 | .20 | .84 | .12 | 17.39 |
| 1886 | .41 | .06 | .50 | 4.84 | 5.44 | 9.44 | 1.12 | .56 | 2.10 | 1.40 | .87 | .14 | 23.55 |
| 1887 | .67 | .44 | 1.28 | 3.88 | 1.26 | 1.11 | 5.32 | .94 | 1.16 | 3.02 | .46 | .10 | 29.89 |
| 1888 | .83 | .53 | .26 | 1.66 | 5.04 | 3.14 | 4.52 | 3.84 | 1.85 | .53 | .43 | .19 | 18.92 |
| 1889 | .16 | .46 | .68 | .98 | 2.91 | 2.02 | 2.47 | 2.93 | .70 | .30 | .57 | .99 | 16.56 |
| 1890 | .02 | .01 | .35 | 4.47 | 5.67 | 2.89 | 5.02 | .67 | 2.41 | 1.72 | .17 | 1.30 | 24.35 |
| 1891 | .08 | .75 | .37 | 1.92 | 6.14 | 9.21 | .90 | 5.48 | 4.89 | 1.93 | .60 | .51 | 31.05 |
| 1892 | 1.52 | .48 | .51 | 4.32 | 4.57 | 4.45 | 2.93 | 4.73 | 4.41 | .96 | 2.13 | .13 | 39.45 |
| 1893 | .22 | 1.54 | .72 | 1.56 | 5.46 | 6.96 | 8.85 | .01 | 8.71 | .00 | .51 | .15 | 25.62 |
| 1894 | 1.44 | .09 | .72 | 1.57 | 4.10 | 5.53 | 6.13 | 2.41 | 2.19 | .08 | .07 | .16 | 26.82 |
| 1895 | 1.21 | .66 | .93 | 4.15 | 6.54 | 6.74 | 5.81 | .93 | 3.81 | .74 | .16 | .08 | 33.88 |

TABLE NO. V.

Precipitation in Drainage Basin of North Platte River above North Platte, Nebraska.
Drainage Area 28,520 sq. mi.

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Annual |
|--------|------|------|------|------|------|------|------|------|-------|------|------|------|--------|
| Normal | .45 | .54 | .93 | 1.86 | 2.44 | 3.11 | 1.93 | 1.32 | .96 | .71 | .26 | .47 | 13.86 |
| 1885 | .60 | .37 | .55 | .60 | 1.71 | 3.36 | 1.26 | .77 | .25 | .23 | .65 | .23 | 10.67 |
| 1886 | .64 | .34 | 1.00 | 1.83 | 1.71 | 3.65 | 1.88 | 1.12 | .57 | .70 | .45 | .05 | 13.40 |
| 1887 | .37 | .47 | 1.76 | 1.41 | 1.37 | 1.26 | 1.55 | 1.96 | .47 | 1.07 | .60 | .74 | 14.06 |
| 1888 | .80 | .23 | .79 | 1.74 | 3.41 | 1.75 | 1.85 | .83 | .78 | .63 | .71 | .39 | 14.28 |
| 1889 | .80 | .83 | 1.64 | .79 | 3.18 | 1.67 | 1.55 | 1.33 | .51 | 1.12 | .45 | .41 | 14.28 |
| 1890 | .65 | .97 | .29 | 1.31 | .92 | .71 | 1.37 | 1.19 | 1.19 | .54 | .20 | .44 | 12.69 |
| 1891 | .04 | .56 | 1.00 | .06 | 2.72 | 1.86 | 1.75 | 1.17 | 1.09 | .87 | .25 | .58 | 14.11 |
| 1892 | .24 | .49 | 1.12 | 1.93 | 4.71 | 1.79 | 1.75 | .99 | 2.10 | .90 | .14 | .34 | 15.10 |
| 1893 | .19 | .91 | .84 | 3.32 | .03 | 1.71 | 2.11 | 1.79 | 1.56 | .51 | .28 | .22 | 13.60 |
| 1894 | 1.24 | .25 | .75 | .92 | 2.77 | 2.71 | .86 | .92 | 1.06 | .99 | .02 | .21 | 13.16 |
| 1895 | 1.04 | .62 | .77 | 3.45 | 3.43 | 1.12 | 6.71 | 3.25 | 1.32 | .82 | .62 | .14 | 18.24 |

FLOW OF NEBRASKA STREAMS—RELATION TO RAINFALL 23

TABLE NO. VI.

Precipitation in Drainage Basin of Republican River above Bostwick, Neb.
Drainage Area 22,000 sq. mi.

| | Apr. | June | July | Aug. | Oct. | Jan. | Mar. | Sept. | May | Feb. | Nov. | Dec. | Annual |
|--------|------|------|------|------|------|------|------|-------|-----|------|------|------|--------|
| Normal | | | | | | | | | | | | | 22.12 |
| 1886 | | | | | | | | | | | | | 18.34 |
| 1896 | | | | | | | | | | | | | 22.88 |
| 1897 | | | | | | | | | | | | | 24.38 |
| 1898 | | | | | | | | | | | | | 21.28 |
| 1899 | | | | | | | | | | | | | 16.09 |
| 1900 | | | | | | | | | | | | | 18.95 |
| 1901 | | | | | | | | | | | | | 27.36 |
| 1902 | | | | | | | | | | | | | 28.28 |
| 1903 | | | | | | | | | | | | | 23.59 |
| 1904 | | | | | | | | | | | | | 23.05 |
| 1905 | | | | | | | | | | | | | 28.97 |

TABLE NO. VII.

Elkhorn River at Norfolk, Nebraska.
Drainage Area 2,470 sq. mi.

| | 1896 | | | | | | | | Total |
|----------------------|--------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Rainfall | Apr. | May | June | July | Aug. | Sept. | Oct. | | |
| Run-off | | | | .15 | 1.25 | .08 | .10 | | .43 |
| Per cent of Rainfall | | | | 2.9 | 8.0 | 3.2 | 4.5 | | 4.0 |
| | 1897 | | | | | | | | Total |
| Rainfall | | 1.17 | 3.65 | 2.74 | 2.77 | 2.09 | 3.05 | | 15.47 |
| Run-off | | .25 | .14 | .12 | .09 | .07 | .09 | | .76 |
| Per cent of Rainfall | | 22.3 | 3.8 | 4.4 | 3.2 | 3.3 | 2.9 | | 4.9 |
| | 1898 | | | | | | | | Total |
| Rainfall | 1.59 | 4.97 | 4.56 | 2.54 | 2.42 | 1.23 | 1.09 | | 18.40 |
| Run-off | .21 | .33 | .45 | .15 | .14 | .09 | .12 | | 1.49 |
| Per cent of Rainfall | 13.2 | 6.6 | 9.9 | 5.9 | 5.8 | 7.3 | 11.0 | | 8.1 |
| | 1899 | | | | | | | | Total |
| Rainfall | 1.01 | 6.72 | 4.67 | 2.66 | 3.06 | 1.04 | .72 | | 18.88 |
| Run-off | .22 | .35 | .24 | .17 | .12 | .08 | .10 | | 1.28 |
| Per cent of Rainfall | 21.8 | 6.1 | 5.1 | 6.4 | 3.9 | 7.7 | 13.9 | | 6.8 |
| | 1900 | | | | | | | | Total |
| Rainfall | 5.21 | 3.05 | 2.10 | 4.62 | 3.52 | 3.29 | 3.12 | | 24.92 |
| Run-off | .27 | .33 | .15 | .10 | .09 | .10 | .13 | | 1.17 |
| Per cent of Rainfall | 5.3 | 10.8 | 7.1 | 2.2 | 2.5 | 3.0 | 4.2 | | 4.7 |
| | 1901 | | | | | | | | Total |
| Rainfall | 2.06 | 2.45 | 8.37 | .58 | .96 | 7.62 | 2.05 | | 24.10 |
| Run-off | .29 | .23 | .57 | .35 | .08 | .12 | .15 | | 1.79 |
| Per cent of Rainfall | 14.0 | 9.3 | 6.8 | 60.0 | 8.3 | 1.5 | 7.3 | | 7.4 |
| | 1902 | | | | | | | | Total |
| Rainfall | 1.86 | 2.71 | 5.51 | 6.61 | 4.57 | 4.75 | .81 | | 26.82 |
| Run-off | .29 | .29 | .22 | .33 | .16 | .29 | .59 | | 2.17 |
| Per cent of Rainfall | 15.6 | 10.7 | 4.0 | 5.0 | 3.5 | 6.1 | 7.3 | | 8.1 |
| | 1903 | | | | | | | | Total |
| Rainfall | 2.35 | 7.22 | 2.88 | 6.50 | 5.52 | 1.14 | 1.80 | | 27.41 |
| Run-off | .39 | .75 | .90 | .47 | .55 | .24 | .12 | | 3.42 |
| Per cent of Rainfall | 16.6 | 10.4 | 31.2 | 7.2 | 10.0 | .21 | 6.7 | | 12.5 |
| | 8-year Means | | | | | | | | Total |
| Rainfall | 2.34 | 3.90 | 3.96 | 3.92 | 3.01 | 2.96 | 1.86 | | |
| Run-off | .28 | .35 | .34 | .23 | .16 | .13 | .17 | | |
| Per cent of Rainfall | 12.0 | 9.2 | 8.6 | 5.9 | 5.3 | 4.4 | 9.1 | | |
| | Summary | | | | | | | | Total |
| Rainfall | 1896 | 1897 | 1898 | 1899 | 1900 | 1901 | 1902 | 1903 | Av. |
| Run-off | 11.19 | 15.47 | 18.40 | 18.88 | 24.92 | 24.10 | 26.82 | 27.41 | 21.10 |
| Per cent Rainfall | .43 | .76 | 1.49 | 1.28 | 1.17 | 1.79 | 2.17 | 3.42 | 1.54 |
| | 4.0 | 4.9 | 8.1 | 6.8 | 4.7 | 7.4 | 8.1 | 12.5 | 7.3 |

TABLE NO. VIII.

Niobrara River at Valentine, Nebraska.
Drainage Area 6,070 sq. mi.

| | | | | | | | | | | |
|----------------------------|------|------|------|-------|-------|-------|-------|--------------|------|-------|
| 1901 | | | | | | | | | | |
| Rainfall | | | | | 1.49 | 2.44 | 3.38 | 2.31 | .03 | 9.65 |
| Run-off | | | | | .111 | .109 | .162 | .150 | .162 | .704 |
| Per cent Rain | | | | | 7.4 | 4.5 | 4.8 | 6.5 | .540 | 7.3 |
| 1902 | | | | | | | | | | |
| Rainfall | 1.84 | 1.08 | 2.60 | 3.73 | 2.26 | 2.77 | 1.34 | .80 | .41 | 16.83 |
| Run-off | .218 | .170 | .150 | .130 | .150 | .130 | .120 | .140 | .150 | 1.358 |
| Per cent Rain | 11.8 | 15.7 | 5.8 | 3.5 | 6.6 | 5.7 | 9.7 | 17.5 | 36.6 | 8.1 |
| 1903 | | | | | | | | | | |
| Rainfall | .81 | 1.72 | 3.27 | 1.66 | 5.74 | 2.81 | 1.52 | .63 | .09 | 17.25 |
| Run-off | .258 | .180 | .151 | .127 | .173 | .160 | .117 | .130 | .132 | 1.428 |
| Per cent Rain | 32.3 | 10.4 | 4.6 | 7.6 | 3.0 | 5.7 | 7.7 | 20.6 | .147 | 8.3 |
| 1904 | | | | | | | | | | |
| Rainfall | .28 | .70 | 2.68 | 5.08 | 3.00 | 2.56 | 1.93 | 1.28 | .08 | 17.59 |
| Run-off | .131 | .124 | .134 | .153 | .128 | .122 | .115 | .144 | .147 | 1.198 |
| Per cent Rain | .48 | 17.7 | 5.0 | 3.0 | 4.3 | 4.8 | 6.0 | 11.2 | .184 | 6.8 |
| 1905 | | | | | | | | | | |
| Rainfall | 1.09 | 2.90 | 5.24 | 5.79 | 4.51 | 1.69 | .97 | 1.16 | .50 | 23.85 |
| Run-off | .179 | .162 | .170 | .185 | .266 | .172 | .140 | .148 | .160 | 1.582 |
| Per cent Rain | 16.4 | 5.6 | 3.2 | 3.2 | 5.9 | 10.2 | 14.4 | 12.7 | 32.0 | 6.6 |
| 5-year Averages. | | | | | | | | | | |
| Rainfall | 1.00 | 1.60 | 3.45 | 4.06 | 3.40 | 2.45 | 1.83 | 1.24 | .22 | |
| Run-off | .196 | .159 | .151 | .149 | .166 | .139 | .131 | .152 | .150 | |
| Per cent Rain | 19.6 | 9.9 | 4.4 | 3.7 | 4.9 | 5.7 | 7.2 | 12.2 | 68.0 | |
| Summary | | | | | | | | | | |
| Rainfall | | | 1901 | 1902 | 1903 | 1904 | 1905 | Av. 4 years. | | |
| Run-off | | | 9.65 | 16.83 | 17.25 | 17.59 | 23.85 | 18.88 | | |
| Per cent of Rainfall | | | .704 | 1.385 | 1.428 | 1.198 | 1.582 | 1.398 | | |
| | | | 7.3 | 8.1 | 8.3 | 6.8 | 6.6 | 7.4 | | |

TABLE NO IX.
Loup River at Columbus.

Drainage Area 13,540 sq. mi.

| | | | | | | | | | |
|----------------------------|------|------|------|------|------|-------|------|-------|--|
| 1895 | | | | | | | | | |
| | Apr. | May | June | July | Aug. | Sept. | Oct. | Total | |
| Rainfall | 2.06 | 2.48 | 4.76 | .98 | 2.49 | 1.81 | .20 | 16.78 | |
| Run-off | .202 | .254 | .296 | .181 | .195 | .200 | .209 | 1.577 | |
| Per cent of Rainfall | 9.8 | 10.2 | 6.2 | 18.5 | 7.8 | 11.0 | .104 | 9.4 | |
| 1896 | | | | | | | | | |
| Rainfall | 4.84 | 2.54 | 4.94 | 4.12 | .89 | 2.10 | 1.40 | 20.83 | |
| Run-off | 3.48 | .254 | .253 | .230 | .226 | .203 | .232 | 1.746 | |
| Per cent of Rainfall | 7.2 | 10.0 | 5.1 | 5.6 | 25.4 | 9.7 | 16.6 | 8.4 | |
| 1897 | | | | | | | | | |
| Rainfall | 3.88 | 1.26 | 4.11 | 2.53 | 2.96 | 1.16 | 3.02 | 18.92 | |
| Run-off | .300 | .210 | .200 | .200 | .200 | .160 | .360 | 1.630 | |
| Per cent of Rainfall | 7.7 | 16.7 | 4.9 | 7.9 | 6.8 | 13.8 | 11.9 | 8.6 | |
| 1898 | | | | | | | | | |
| Rainfall | 1.66 | 5.04 | 2.34 | 2.88 | 2.84 | 1.35 | .83 | 16.94 | |
| Run-off | .230 | .300 | .330 | .160 | .230 | .170 | .210 | 1.630 | |
| Per cent of Rainfall | 13.9 | 6.0 | 14.1 | 5.6 | 8.1 | 12.6 | 25.6 | 9.6 | |
| 1899 | | | | | | | | | |
| Rainfall | .98 | 2.91 | 3.92 | 2.47 | 2.93 | .80 | .29 | 14.20 | |
| Run-off | .267 | .250 | .330 | .200 | .200 | .180 | .160 | 1.587 | |
| Per cent of Rainfall | 27.2 | 8.6 | 8.4 | 8.1 | 6.8 | 25.7 | 55.2 | 11.2 | |
| 1900 | | | | | | | | | |
| Rainfall | 4.47 | 2.57 | 2.30 | 5.50 | 3.67 | 2.41 | 1.72 | 22.64 | |
| Run-off | .280 | .310 | .290 | .280 | .300 | .290 | .280 | 20.20 | |
| Per cent of Rainfall | 6.3 | 12.1 | 12.6 | 5.1 | 8.2 | 11.6 | 16.3 | 8.9 | |
| 1901 | | | | | | | | | |
| Rainfall | 1.92 | 1.61 | 4.92 | .90 | 1.58 | 4.89 | 1.93 | 17.75 | |
| Run-off | .270 | .200 | .290 | .200 | .200 | .230 | .200 | 1.590 | |
| Per cent of Rainfall | 14.1 | 12.4 | 5.9 | 22.2 | 12.6 | 4.7 | 10.4 | 9.0 | |
| 1902 | | | | | | | | | |
| Rainfall | 1.42 | 4.27 | 4.45 | 6.29 | 3.77 | 3.44 | 1.95 | 25.59 | |
| Run-off | .200 | .280 | .270 | .480 | .400 | .270 | .250 | 2.150 | |
| Per cent of Rainfall | 14.1 | 6.6 | 6.1 | 7.6 | 10.6 | 7.8 | 12.8 | 8.4 | |
| 1903 | | | | | | | | | |
| Rainfall | 1.56 | 5.46 | 1.68 | 6.88 | 5.01 | .87 | 1.00 | 22.46 | |
| Run-off | .331 | .347 | .262 | .292 | .458 | .228 | .237 | 2.155 | |
| Per cent of Rainfall | 21.2 | 6.4 | 15.6 | 4.2 | 9.1 | 26.2 | 23.7 | 9.6 | |

FLOW OF NEBRASKA STREAMS—RELATION TO RAINFALL 25

| | | | | | | | | | | | | |
|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1904 | | | | | | | | | | | | |
| Rainfall | 1.57 | 4.10 | 5.53 | 6.13 | 2.41 | 2.24 | 3.08 | 25.06 | | | | |
| Run-off | .275 | .251 | .359 | .362 | .200 | .195 | .250 | 1.892 | | | | |
| Per cent of Rainfall | 17.5 | 6.1 | 6.5 | 5.9 | 8.3 | 8.7 | 8.1 | 7.5 | | | | |
| 1905 | | | | | | | | | | | | |
| Rainfall | 4.15 | 6.54 | 6.07 | 4.58 | 1.93 | 3.81 | .74 | 27.82 | | | | |
| Run-off | .453 | .738 | .668 | .772 | .591 | .464 | .347 | 4.033 | | | | |
| Per cent of Rainfall | 10.9 | 11.3 | 11.0 | 16.8 | 30.6 | 12.2 | 46.9 | 14.5 | | | | |
| Ten Year Means | | | | | | | | | | | | |
| Rainfall | 2.88 | 3.13 | 4.16 | 3.59 | 2.36 | 2.03 | 1.39 | 19.59 | | | | |
| Run-off | .290 | .310 | .323 | .305 | .291 | .234 | .248 | | | | | |
| Per cent of Rainfall | 10.0 | 9.7 | 7.8 | 8.5 | 12.3 | 11.5 | 17.8 | | | | | |
| Summary | | | | | | | | | | | | |
| Totals for 7-mo periods | | | | | | | | | | | | |
| | 1895 | 1896 | 1897 | 1898 | 1899 | 1900 | 1901 | 1902 | 1903 | 1904 | 1905 | Av. |
| Rainfall | 16.78 | 20.83 | 18.97 | 16.94 | 14.20 | 22.64 | 17.75 | 25.59 | 22.46 | 25.06 | 27.82 | 20.82 |
| Run-off | 1.58 | 1.75 | 1.63 | 1.63 | 1.59 | 2.02 | 1.59 | 2.15 | 2.16 | 1.89 | 4.03 | 2.00 |
| Per cent of Rainfall | 9.4 | 8.4 | 8.6 | 9.6 | 11.2 | 8.9 | 9.0 | 8.4 | 9.6 | 7.5 | 14.5 | 9.6 |

TABLE NO. X.

North Platte River at North Platte, Nebraska.
Drainage Area 28,520 sq mi.

| 1896 | | | | | | | | | | | |
|----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Rainfall | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Total | | |
| Run-off | 1.83 | 2.17 | 2.65 | 1.88 | 1.12 | .57 | .70 | .45 | 11.37 | | |
| Per cent of Rainfall | .100 | .180 | .240 | .046 | .037 | .033 | .046 | .083 | .765 | | |
| | 5 | 8 | 9 | 2 | 3 | 6 | 7 | 18 | 6.7 | | |
| 1897 | | | | | | | | | | | |
| Rainfall | 1.41 | 1.37 | 1.26 | 1.55 | 1.96 | .47 | 1.07 | .60 | 9.69 | | |
| Run-off | .200 | .565 | .545 | .149 | .116 | .024 | .046 | .084 | 1.729 | | |
| Per cent of Rainfall | 14 | 41 | 43 | 10 | 6 | 5 | 4 | 14 | 17.9 | | |
| 1898 | | | | | | | | | | | |
| Rainfall | 1.12 | 4.34 | 1.75 | 1.68 | .83 | .78 | .63 | .74 | 11.87 | | |
| Run-off | .100 | .210 | .270 | .080 | .010 | .010 | .020 | .040 | .740 | | |
| Per cent of Rainfall | 9 | 5 | 15 | 5 | 1 | 1 | 3 | 5 | 6.2 | | |
| 1899 | | | | | | | | | | | |
| Rainfall | .79 | 3.18 | 1.67 | 1.55 | 1.23 | .51 | 1.22 | .45 | 10.60 | | |
| Run-off | .260 | .370 | .550 | .440 | .160 | .040 | .039 | .070 | 1.929 | | |
| Per cent of Rainfall | 33 | 12 | 33 | 28 | 13 | 8 | 3 | 16 | 18.2 | | |
| 1900 | | | | | | | | | | | |
| Rainfall | 4.34 | .91 | .81 | 2.39 | .58 | 1.19 | .54 | .20 | 10.96 | | |
| Run-off | .160 | .380 | .420 | .090 | .020 | .004 | .020 | .040 | 1.134 | | |
| Per cent of Rainfall | 4 | 42 | 52 | 4 | 3 | 0.3 | 4 | 20 | 10.3 | | |
| 1901 | | | | | | | | | | | |
| Rainfall | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Total | | |
| Run-off | 2.06 | 2.78 | 2.66 | .75 | 1.17 | 1.09 | .87 | .25 | 11.63 | | |
| Per cent of Rainfall | .090 | .310 | .380 | .060 | .010 | .040 | .050 | .070 | 1.01 | | |
| | 4 | 11 | 14 | 8 | 1 | 0.4 | 6 | 28 | 8.8 | | |
| 1902 | | | | | | | | | | | |
| Rainfall | 1.26 | 2.47 | 2.70 | 1.75 | .99 | 2.10 | .90 | .14 | 12.31 | | |
| Run-off | .096 | .220 | .201 | .090 | .005 | .019 | .042 | .043 | .716 | | |
| Per cent of Rainfall | 8 | 9 | 7 | 5 | 0.5 | 9 | 5 | 31 | 5.8 | | |
| 1903 | | | | | | | | | | | |
| Rainfall | 1.33 | 2.03 | 1.71 | 2.11 | 1.79 | 1.56 | .51 | .26 | 11.30 | | |
| Run-off | .126 | .197 | .267 | .135 | .029 | .021 | .044 | .045 | .864 | | |
| Per cent of Rainfall | 9 | 10 | 16 | 6 | 2 | 1 | 9 | 17.3 | 7.6 | | |
| 1904 | | | | | | | | | | | |
| Rainfall | .99 | 2.87 | 2.97 | 1.86 | .92 | 1.09 | .99 | .02 | 11.70 | | |
| Run-off | .076 | .228 | .402 | .149 | .016 | .006 | .047 | .059 | .983 | | |
| Per cent of Rainfall | 8 | 8 | 14 | 8 | 2 | 0.5 | 5 | 295 | 8.4 | | |
| 1905 | | | | | | | | | | | |
| Rainfall | 3.45 | 3.43 | 2.11 | 2.67 | 1.25 | 1.32 | .82 | .62 | 15.67 | | |
| Run-off | .146 | .415 | .575 | .242 | .075 | .023 | .025 | .030 | 1.531 | | |
| Per cent of Rainfall | 4 | 12 | 27 | 9 | 6 | 2 | 3 | 5 | 9.8 | | |
| Ten Year Means. | | | | | | | | | | | |
| Rainfall | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | | | |
| Run-off | 2.66 | 2.56 | 2.03 | 1.82 | 1.18 | 1.07 | .82 | .37 | | | |
| Per cent of Rainfall | .135 | .308 | .385 | .148 | .048 | .022 | .038 | .056 | | | |
| | 5.1 | 12.0 | 19.0 | 8.1 | 4.0 | 2.0 | 4.0 | 15.1 | | | |
| Summary. | | | | | | | | | | | |
| Rainfall | 1896 | 1897 | 1898 | 1899 | 1900 | 1901 | 1902 | 1903 | 1904 | 1905 | Av. |
| Run-off | 11.37 | 9.69 | 11.87 | 10.60 | 10.96 | 11.63 | 12.31 | 11.30 | 11.70 | 15.67 | 11.71 |
| Per cent of Rain | .765 | 1.729 | .740 | 1.929 | 1.134 | 1.010 | .716 | .864 | .983 | 1.531 | 1.140 |
| | 6.7 | 17.9 | 6.2 | 18.2 | 10.3 | 8.8 | 5.8 | 7.6 | 8.4 | 9.8 | 9.7 |

TABLE NO. XI.

Republican River at Bostwick, Nebraska.
Drainage Area 22,000 sq. mi.

| 1896 | | | | | | | | | | | |
|--|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Rainfall | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Total | | |
| Run-off | | | 3.55 | 2.69 | 2.64 | 1.87 | 1.44 | .59 | 12.78 | | |
| Per cent of Rainfall | | | .033 | .06 | .03 | .01 | .012 | .022 | .167 | | |
| | | | 0.9 | 2.2 | 1.1 | 0.5 | 0.8 | 3.7 | 1.3 | | |
| 1897 | | | | | | | | | | | |
| Rainfall | 3.95 | 1.22 | 4.58 | 2.12 | 3.05 | 1.40 | ..... | ..... | 16.32 | | |
| Run-off | .06 | .02 | .022 | .05 | .01 | .003 | ..... | ..... | .165 | | |
| Per cent of Rainfall | 1.5 | 1.6 | 0.5 | 2.4 | 3.3 | 0.2 | ..... | ..... | 1.0 | | |
| 1898 | | | | | | | | | | | |
| Rainfall | 2.77 | 4.72 | 3.35 | 2.17 | 1.55 | 4.13 | .88 | .55 | 20.07 | | |
| Run-off | .033 | .06 | .07 | .02 | .01 | .01 | .01 | .022 | .235 | | |
| Per cent of Rainfall | 1.2 | 1.3 | 2.1 | 0.9 | 0.7 | 0.2 | 1.1 | 4.0 | 1.1 | | |
| 1899 | | | | | | | | | | | |
| Rainfall | .65 | 2.94 | 3.74 | 3.67 | 1.79 | .22 | .42 | .24 | 13.67 | | |
| Run-off | .03 | .03 | .02 | .02 | .02 | .002 | .002 | .004 | .128 | | |
| Per cent of Rainfall | 4.6 | 1.0 | 0.5 | 0.5 | 1.1 | 0.9 | 0.5 | 1.7 | 0.9 | | |
| 1900 | | | | | | | | | | | |
| Rainfall | 4.45 | 1.50 | 2.42 | 3.05 | 2.28 | 1.54 | .87 | .28 | 16.39 | | |
| Run-off | .04 | .03 | .02 | .01 | .01 | .007 | .003 | .021 | .141 | | |
| Per cent of Rainfall | 0.9 | 2.0 | 1.2 | 3.3 | 0.4 | 0.5 | 0.3 | 0.8 | 0.9 | | |
| (a) Records for 1896 to 1903 obtained at Superior. | | | | | | | | | | | |
| 1901 | | | | | | | | | | | |
| Rainfall | 3.28 | .96 | 3.13 | 1.10 | 3.35 | 3.97 | .75 | .28 | 16.44 | | |
| Run-off | .05 | .02 | .01 | .002 | .003 | .06 | .02 | .021 | .186 | | |
| Per cent of Rainfall | 1.5 | 2.1 | 0.3 | 0.2 | 0.1 | 1.5 | 2.7 | 7.5 | 1.1 | | |
| 1902 | | | | | | | | | | | |
| Rainfall | .86 | 5.52 | 4.67 | 5.41 | 2.35 | 4.01 | 2.22 | .14 | 25.18 | | |
| Run-off | .02 | .07 | .07 | .16 | .03 | .06 | .05 | .03 | .490 | | |
| Per cent of Rainfall | 2.3 | 1.3 | 1.5 | 2.9 | 1.3 | 1.5 | 2.3 | 22.4 | 1.9 | | |
| 1903 | | | | | | | | | | | |
| Rainfall | 1.38 | 7.14 | 1.85 | 4.67 | 3.61 | .53 | 1.08 | .70 | 20.96 | | |
| Run-off | .05 | .23 | .10 | .10 | .06 | .02 | .017 | .021 | .598 | | |
| Per cent of Rainfall | 3.6 | 3.2 | 5.4 | 2.1 | 1.7 | 3.8 | 1.6 | 3.0 | 2.9 | | |
| 1904 | | | | | | | | | | | |
| Rainfall ..... | ..... | ..... | 5.48 | 3.23 | 2.82 | 1.83 | 2.61 | .07 | 16.04 | | |
| Run-off ..... | ..... | ..... | .079 | .086 | .025 | .009 | .026 | .027 | .252 | | |
| Per cent of Rainfall | ..... | ..... | 1.4 | 2.7 | 0.9 | 0.4 | 1.0 | .38 | 1.6 | | |
| Rainfall | 3.70 | 4.56 | 4.63 | 6.53 | 1.98 | 2.45 | 1.03 | ..... | 24.88 | | |
| Run-off | .053 | .100 | .149 | .300 | .161 | .037 | .025 | ..... | .825 | | |
| Per cent of Rainfall | 1.4 | 2.2 | 3.2 | 4.6 | 8.1 | 1.5 | 2.4 | ..... | 3.5 | | |
| 1905 | | | | | | | | | | | |
| Ten Year Means. | | | | | | | | | | | |
| Rainfall | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | | | |
| Run-off | 2.63 | 3.57 | 3.74 | 3.46 | 2.64 | 2.20 | 1.23 | .36 | | | |
| Per cent of Rainfall | .04 | .042 | .057 | .081 | .036 | .022 | .018 | .021 | | | |
| | 1.5 | 2.0 | 1.5 | 2.3 | 1.4 | 1.0 | 1.5 | 5.6 | | | |
| Summary. | | | | | | | | | | | |
| Rainfall | 1896 | 1897 | 1898 | 1899 | 1900 | 1901 | 1902 | 1903 | 1904 | 1905 | Av. |
| Run-off | 12.78 | 16.32 | 20.07 | 13.67 | 16.39 | 16.44 | 25.18 | 20.96 | 16.04 | 24.88 | 18.47 |
| Per cent of Rain | .167 | .165 | .237 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .319 |
| | 1.3 | 1.0 | 1.1 | 0.9 | 0.9 | 1.1 | 1.9 | 2.9 | 1.6 | 3.3 | 1.7 |

THE DEVELOPMENT OF TELEPHONE TRANSMISSION.

By A. R. Swoboda, Instructor in Electrical Engineering.

It is sometimes said that good theory is also good practice and, conversely, that good practice is good theory. Theory tries to predict what will work satisfactorily in practice, and if these predictions fail, it is because some unknown or unforeseen disturbing factor has entered in. Sometimes in the working out of a problem no difficulty is anticipated; that is we believe the theoretical solution to be correct. The plan is at once put to a practical test and alas, we get results far from those anticipated. On investigating, either experimentally or otherwise, we find that there are factors which distort the sought for results. We find that, had we known the nature of these disturbing factors and their true action in amount and effect, failure could have been forestalled.

It is thus seen that so called theory and practice go hand in hand, whirling each other around temporary pivots toward their common goal. Such have been all developments and so it was with telephone transmission. Thus in 1844 Morse constructed his experimental telegraph line between Baltimore and Washington, in which he is said to have attempted the use of gutta percha insulated wire laid in a trench dug in the earth. On account of the difficulty of maintaining a high degree of insulation, due to the poor material then at his disposal, this method of laying wires was inadequate and recourse was had to the aerial line. The success of the overhead line soon made it the standard of construction for telegraphy.

In 1837 the discovery by Steinheil that the earth could serve as a return conductor, was on account of the accompanying saving (an important influence in the practice of new industry) put into ready practise. We therefore find that even into the 80's the standard telegraph line was a grounded, iron wire pole line.

It is hard to estimate the influence which telegraphy had on the transmission of speech. Being much older it was from its fold that many of the early recruits in the telephone field were drawn and records show that most of the devices were adaptations from telegraphy. Therefore it is not at all strange that when the first telephone exchange was constructed in Boston in 1877, the telephone line likewise followed closely the standard found

serviceable for telegraphy. Even up to the year 1885 this method of construction was still common.

As soon as the telephone business had developed to some magnitude and with the increase in lighting and trolley circuits it became necessary to substitute the full metallic for the grounded line, on account of the excessive noises present in the latter.

It also developed that iron wire was thoroly inadequate for the longer lines on account of its high resistance and its magnetic qualities. About 1885 we find that as a rule the limit to telephonic conversation was between 80 miles to 100 miles and in the majority of cases unintelligible beyond 50 miles.

Copper altho superior to iron in its transmitting qualities and life, could not be used for various reasons. First was its high cost, and second its low tensile strength. The price of copper, due to the electrolytic refining process, steadily decreased so that it was no longer prohibitive* but the low tensile strength and elasticity prevented its use at any price, since a soft copper wire would break if stretched as a span between poles. The conductivity had steadily increased from 42 per cent in the Calais Dover cable in 1851 to 96 per cent for the Atlantic cable in 1865.

When therefore Mr. Doolittle discovered the processes of "hard drawing" copper, that is that copper could be given a hard surface by drawing it through dies without heating, which would give it a tensile strength nearly equal to that of steel, he may be said to have created a new epoch in long distance telephony.*

Experiments were made in 1883 and 1884 by the American Bell Telephone Company on a copper line built for this purpose between New York and Boston. Altho this line was 300 miles in length, yet it gave results as good as any of the short commercial lines then in use. As a result of these experiments the American Telephone and Telegraph Company was organized to conduct a long distance service.

As an example of the growth of this service we find on January 1st, 1890 in use 1,919 miles of long distance pole line with 34,800 miles of copper wire, beside 806 miles in various aerial, underground and service cable. This was an increase of 700 miles of pole line and 9,588 miles of wire for one year.** These developments in long distance service had a marked influence for the better design of local lines.

It required but little time to show that the telephone lines were subject to disturbances due to induction. Induction is

*The cost of a copper conductor is only about 2-5 of total cost of line complete, therefore the saving in the use of iron instead of copper is a still smaller proportion of cost.—Abbott's "Telephony."

*Bronze wire altho used to a considerable extent in Europe was never introduced in the United States.

**Prescott's—"The Electric Telephone."

of two kinds, electromagnetic and electrostatic. This induction consists of the transference of energy to a telephone line from any conductor running parallel to it and carrying a variable current. The energy appears in the telephone line as a current and in the telephone as a noise. If the induction is set up by a telephone current in a neighboring wire we may overhear the conversation in that line and the phenomenon is known as "cross-talk." If the induced current is due to the varying magnetic field due to the rapidly varying current in a neighboring conductor, we have electro magnetic induction; whereas if due to the charges of electricity induced by that line, it is called electrostatic induction. In the early days it was thought that all trouble was due to electromagnetic induction and it remained for Mr. Carty to prove the contrary.* Altho the true cause was unknown yet the remedy adopted for the one was effective also for the other. It consists of keeping both wires of a line influenced to the same degree, thus neutralizing the effect. The wires are crossed over every few poles, thus causing each one to be nearer the disturbing conductor for one part of the line and further from it for the next portion of the line. This construction is known as transposition and is very effective in reducing the bad effects of both electromagnetic and electrostatic induction.

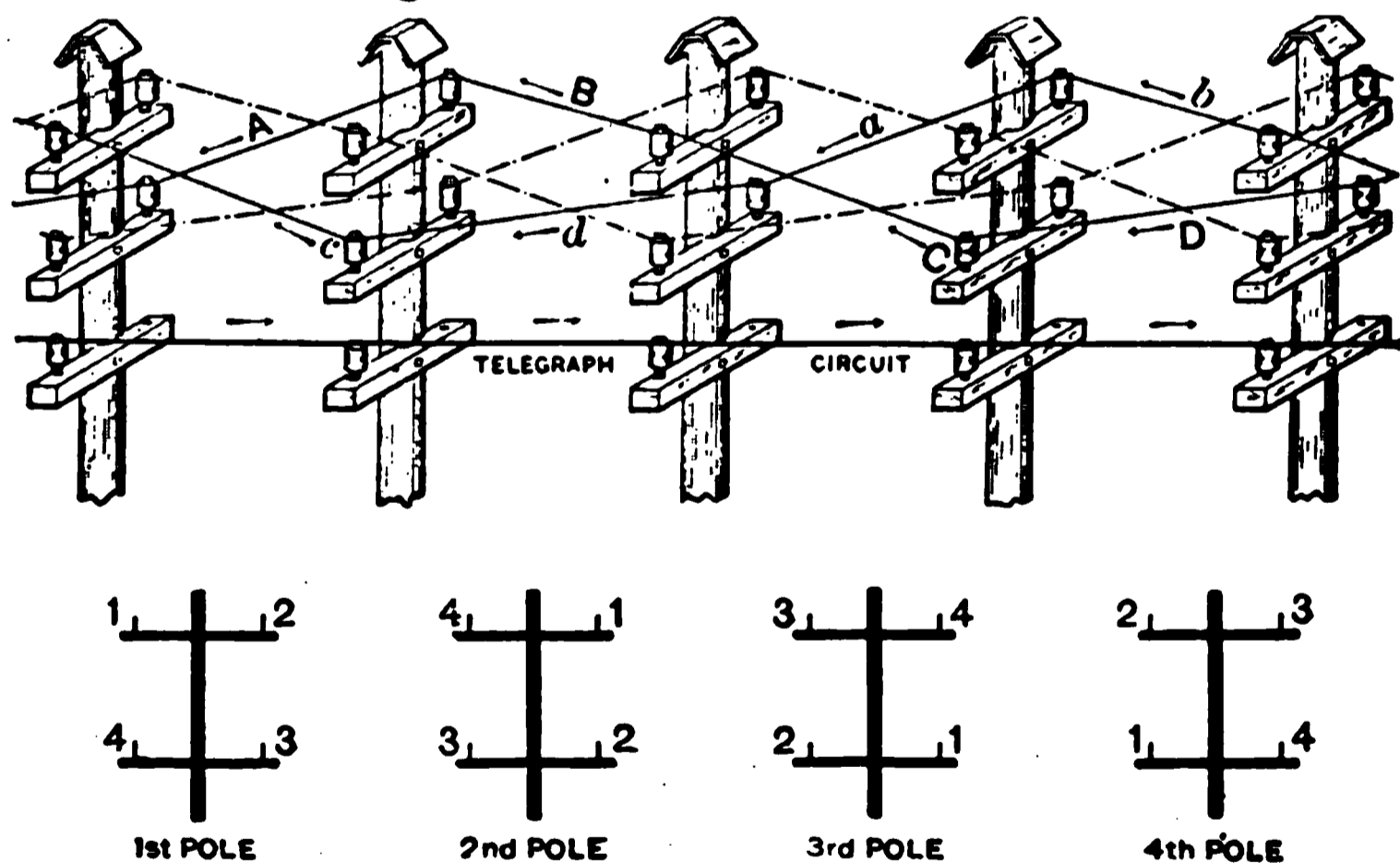


FIG. 1

There are two kinds of transposition in use, one in which the conductors are carried along spirally and that in which they cross each other on only one cross arm. In the spiral system the construction is similar to two insulated conductors twisted

*Carty's Experiments.—American Institute of Electrical Engineers, Vol. VIII, 1891.

together, the twist being very long and the insulation being air. This system was devised by Prof. Hughes and, altho very effective, has been but recently introduced into the United States. Fig. 1 shows the general plan of this type of transposition.

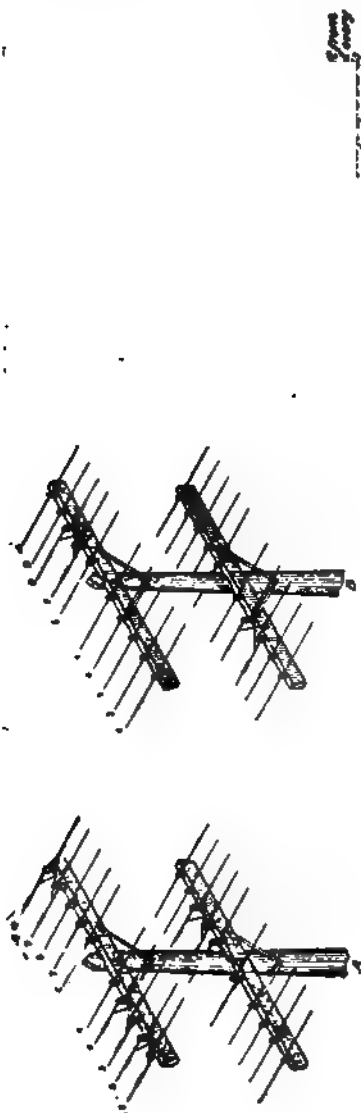


FIG. 2

The second method of transposing wires is shown in Fig. 2 and needs no further comment. This type is in very extensive use at present.

Due to adverse legislation and on account of lower cost and maintenance it became desirable to concentrate the conductors into cable form. This cable is then supported on pole lines or, where more desirable, is placed in ducts underground. It would require considerable space to describe the various forms of cable made and, in some places, still in use.

Even the best cable is so inferior in its transmitting qualities as to prohibit its use for long distance transmission. The limiting factor in a cable is its electrostatic capacity or condenser action which has a tendency to distort the transmitted wave thus making the sound at the receiving end unintelligible or indistinct.

Capacity increases with the size of wire, the proximity of the wires, and the nature of the insulation between them. Among all substances used between the wires dry air gives the least capacity, gutta-percha having two and one-half times that of air. Manufacturers, realizing the importance of these principles, made various attempts to design efficient cable and in time the Patterson or so called "dry core" cable was developed and is the type now in universal use for telephone work.

In the construction of the "dry core" cable dry paper in the form of a ribbon from 3-8 inch to 3-4 inch wide is laid either spirally or longitudinally on each conductor; the object of this paper being to keep the wires apart and yet to contain a great amount of air. This insulation practically gives the cable the low capacity of air. The paper for each wire of a pair has a particular color for ready identification. The pairs are twisted together with a lay of about four inches which is equivalent to transposition in aerial wires. The twisted pairs are formed into regular layers of alternately left and right handed lay. When all the pairs are thus built up a final wrapping is given the whole. The cable is then thoroughly dried in a heated vacuum chamber. After drying, a protecting sheath of lead with a small per cent of tin to give hardness, is forced around the paper cable by means of hydraulic pressure. Today acres of lead sheathing are kept hermetically sealed as the least little pin hole would admit moisture and ruin the cable.

Dry core cable is now made in sizes up to 500 pairs (1000 wires) of No. 19 B. & S. gauge to No. 22 B. & S., and this in a diameter below three inches. Some idea of the important part which cable has played in the development of telephony may be gotten by imagining the space taken up by the same 1000 aerial wires together with the enormous difficulty of maintaining the same.

Van Rysselbergh of the Belgian Administration of Posts and Telegraphs, encouraged by the successful design of inductionless telegraph circuits, succeeded in applying the results to

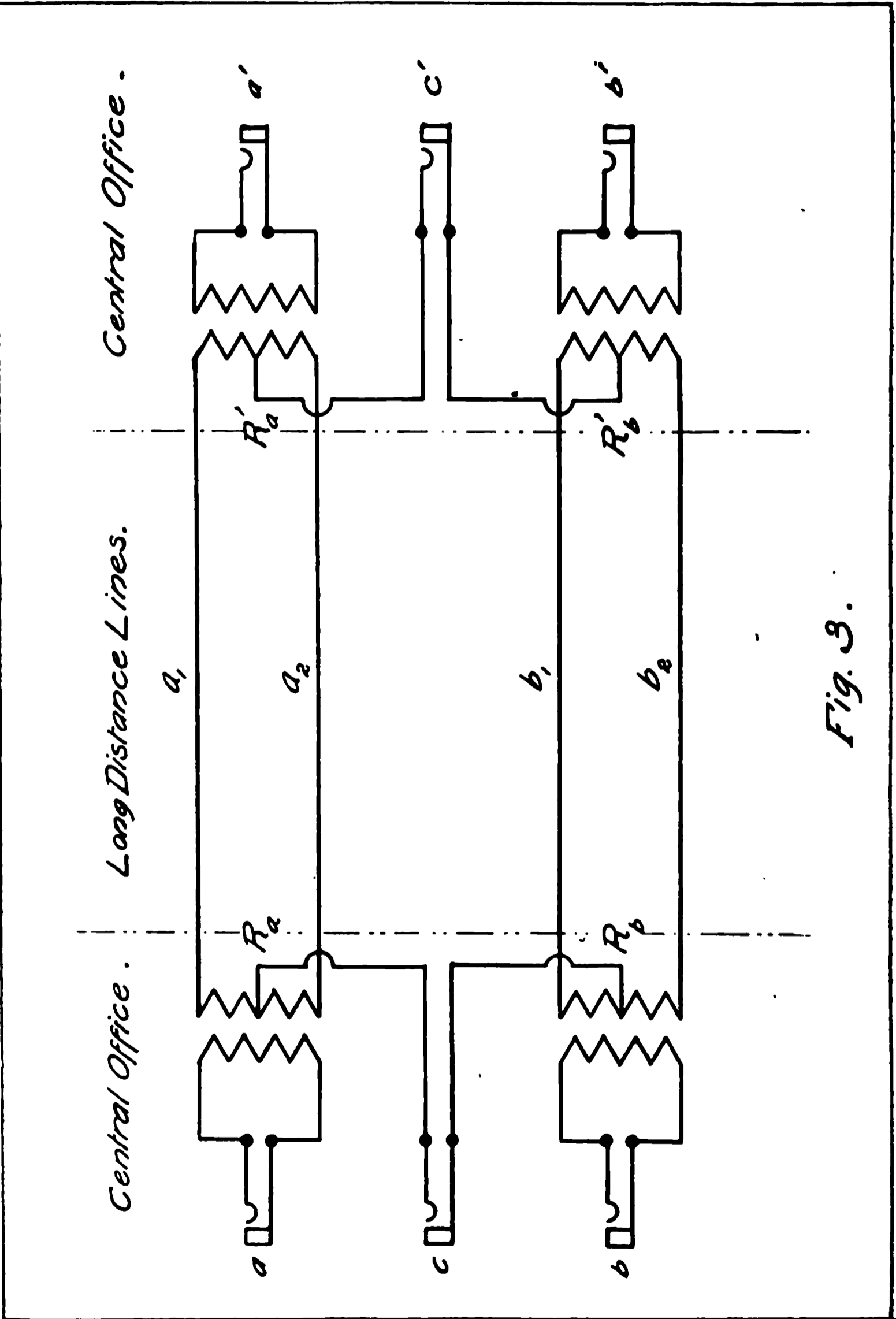


Fig. 3.

FIG. 3

the simultaneous transmission of telegraph and telephone messages over the same circuit. Systems are in use both in Europe and the United States which utilize this principle.

The successful use of the duplex system of telegraphy encouraged the design of telephone systems which would make it possible to transmit more than one speech over wires already in use. The saving in cost is considerable since by using two circuits we can carry on three conversations at one time. Such circuit known as a phantom circuit is shown in Fig. 3.

In this figure a, a', b, b', C, C' , are the jacks at the switch-board and R_a, R'_a, R_b, R'_b the repeating coils,* connected as shown. a_1, a_2, b_1, b_2 are the four wires making up two lines. It will be seen that a conversation can be carried on over each line, being transmitted by means of the repeating coils. If while these conversations are being transmitted a party should be connected to jack C , the currents would reach the middle point of the repeating coil, pass over the two wires a_1 and a_2 reunite at R'_a , go thru a telephone connected at jack C' , divide at coil R'_b , pass over the wires b_1 and b_2 in multiple and, by reuniting at R_b , complete the circuit. It is clear therefore that if the lines are balanced none of the conversation of jack C will get into either of the other two lines and we have been able by means of proper coils to save the expense of two wires, quite an item in long distance work.

It may also be apparent that this plan could be extended by using four lines for seven conversations by combining phantom circuits but this is at present a difficult process.

Time and again inventors have striven to produce a device that would stand to the telephone line in the relation of the telegraph relay to its line, thereby increasing the distance of transmission. Such devices have been patented in large numbers and of varying designs. They consist of some sensitive instrument which, when placed in the circuit, faithfully operates a local device of greater energy. This in turn acts as a new source of transmission, thus exchanging each feeble impulse for one more powerful.

This was easily attained in telegraphy where the impulses are simple, but in telephony too much is expected from the repeater. A telephone wave corresponding to the human voice is of complex nature, having loudness, pitch and quality. It is now well understood that capacity destroys quality, thus making imperfect the speech received. The repeater might be designed to give loudness but that only. If we unreasonably expect it to restore what has been destroyed by the capacity of the line, it must fail.

*A repeating coil may be considered as a transformer with a one to one ratio of transformation.

Early telephonists realized the importance of keeping the resistance and capacity of the circuit low and Sir William Preece after numerous experiments formulated his KR law. He stated that if the product of capacity (K) and resistance (R) of any line exceeded from 5000 to 10,000 for open lines and 8000 for cables such lines would not talk. Soon thereafter lines were built between Chicago and New York with the product far above Preece's danger point and yet the lines talked fairly well.

Since inductance has properties opposite to those of electrostatic capacity many attempts were made to so combine the two that the former may neutralize the distorting tendencies of the latter. Mr. Heaviside showed mathematically that this could be done, but when he attempted to carry out experimentally his mathematical deductions by inserting inductances, the lines would not talk at all.

In 1893 Dr. S. P. Thompson in a paper read before the International Electrical Congress showed two methods for using correcting coils. In the same year two patents were issued to Mr. C. J. Reed based on the same features as those shown in Thompson's paper.

Altho a number of general plans were proposed yet it remained for Dr. M. I. Pupin to give a definite solution both mathematical and practical. Dr. Pupin showed that the inductances suggested by others must be properly designed and placed at predetermined intervals along the line. Experiments conducted at different times show that if the coils be indiscriminately placed failure results, as had been the experience of former investigators.

In order that we may get a conception of electrical wave transmission and also that we may comprehend the reason for former failures due to the hap-hazard spacing of inductances, the hydraulic analogy given in Abbott's Telephony may be of service.

Suppose we have a force pump attached to an elastic hose, if the line of hose be short each stroke of the pump will be followed by a corresponding jet of water from the delivery end. The elastic hose acts in no way to interfere. Suppose now that the column of water be great and the hose long, with short quick strokes of the pump there will now be a deviation, the jets will no longer correspond to the strokes of the pump. The inertia of the water causes the elastic hose to distend at the pump and thereby reflect the waves back upon themselves, thus causing them to interfere. The hose therefore does not reproduce faithfully in jets the waves originated by the pump. A remedy for this distortion would be to counteract this elasticity by encasing the hose in a rigid pipe. Instead of this, wire rings spaced at frequent intervals would give satisfactory results.

A telephone line may be considered in the same light. Inductances correspond to the rigid rings which thus counteract the disturbing effect of the capacity of the line. Former mistakes were due to the fact that these rings were concentrated at a few points thus allowing the intermediate portions to exert their interfering power. It was Dr. Pupin who proved that while the principle of distributed inductance was correct, yet as understood by early investigators it was incomplete.

In order to show the system of loaded lines as designed by Dr. Pupin to be correctly based, the results of practical tests may be given as proof.

Before the Siemens and Halke Company purchased the European patents covering this invention they made exhaustive tests for both cable and aerial lines, substantiating every claim of the inventor.

A cable line between Berlin and Potsdam a distance of 20 miles was put into service. Fourteen pairs of this cable were used in the test, seven of which were supplied with the coils arranged in cast iron boxes as shown in Fig. 4.

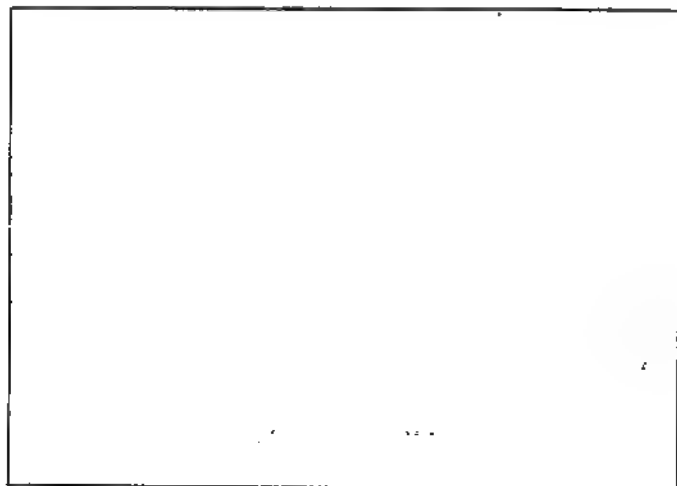


Fig. 4.

Sets of coils were placed about every 2,000 feet. Tests showed that upon this line the conversation could be heard nearly twenty times as far away from the receiver on the loaded lines than those not supplied with coils. With the wires connected so as to give about 250 miles of cable the conversation was clear tho faint. From this experiment it was found that the range of telephone transmission could be extended about fivefold.

Experiments carried out on an aerial line of about 100 miles between Berlin and Magdeburg gave similar results. Tests also showed conclusively the importance of properly spacing the coils.

The American patents are the property of the American Telephone and Telegraph Company which is equipping a number of its lines thus adding to their already strong position in the long distance field.

In closing I would like to submit some data from the annual report to the stockholders of the American Telephone and Telegraph Company by President F. B. Fish, March 26, 1907.

DATA.

| | |
|---|--------------|
| Gross revenue | \$24,526,097 |
| Net output of telephones 1906 | 1,409,578 |
| Total phones in use by Bell Cos. | 7,107,836 |
| Total miles of wire for telephone service | 7,468,905 |
| Total number of exchange connections per day | 16,478,000 |
| Total number of toll connections per day | 462,000 |
| Calls per man, woman and child in U. S. | 64 |
| Added to Construction and Real Estate. | |
| For exchanges | \$59,971,094 |
| For toll lines | 13,585,659 |
| For lands and buildings | 5,810,196 |
| <hr/> | |
| Total | \$79,366,949 |
| Cost of maintenance and reconstruction | \$32,814,568 |

This report includes only the Bell Companies and does not include any of the sub licenses or the Western Electric Company. To these figures would have to be added those for the independents, which would bring the total to a formidable figure.

The study of this subject of telephone transmission would lead one to the following conclusions:

1. That there were certain periods or epochs which may be said to be the following: Early period of telegraph influence, the invention of hard drawing copper, the production of the dry core cable and the invention of the load coils by Pupin.

2. That Dr. Pupin's discovery may make possible the introduction of repeaters thus decreasing the size of the conductors and so reducing the capacity of lines.

3. That with future development it may be possible to use cable for long distance service, thus decreasing the high cost of maintenance due to aerial lines.

4. That attempts are being made to decrease the cost of long distance telephone service by the use of phantom circuits.

5. That the field has now become one requiring high tech-

nical skill and holds out to the proper men opportunities of a most promising nature.

List of Works Consulted.

"American Telephone Practise."—K. B. Miller.

"A Manual of Telephony."—Preece and Stubbs.

"Telephony."—Abbott.

"Telephone Lines."—Owen.

"Telephone Lines and Their Properties"—Hopkins.

"The Electric Telephone."—Prescott.

"Transactions of the American Institute of Electrical Engineers."

"Patent Office Gazette."

Various Technical Periodicals.

DISTRICT HEATING.

By N. A. Kemmish, Lincoln Traction Co.

Every manufacturer shall use all the by-products that is possible. The packers have this reduced to a science. Then why not the central station make use of its by-product, exhaust steam? About the only general use that exhaust steam can be put to is that of heating buildings.

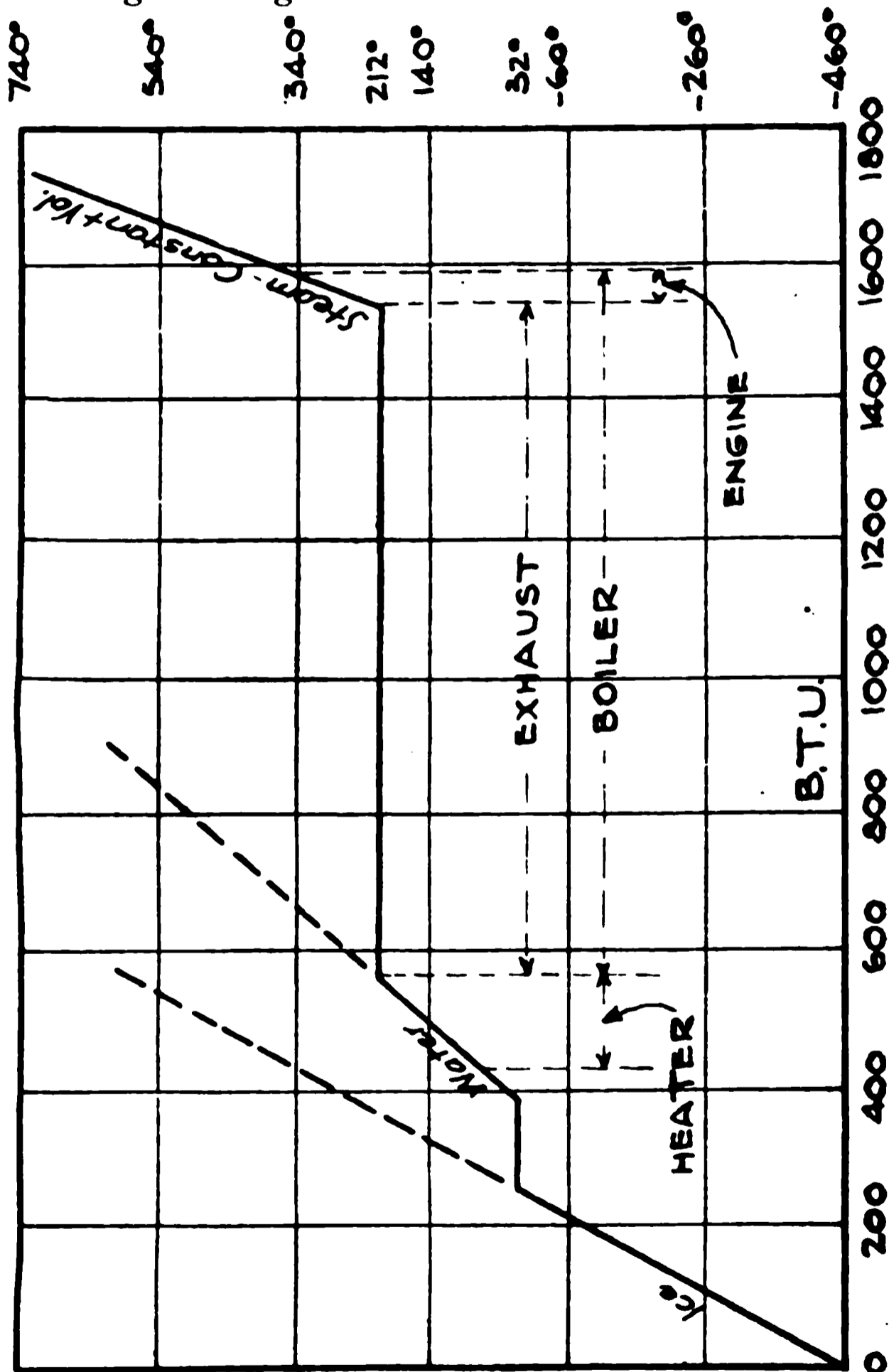


Fig. 1.

A study of chart No. 1 will show what a large percentage of the heat goes out the exhaust. In fact, this is one of the greatest losses a central station has.

The most common methods of district heating now in use by central stations are hot water and steam. These two systems are used quite extensively and both have commendable features and likewise their faults. There are a great many things, however, that are in common to both systems.

In both systems the pipes are usually placed in the ground below the frost line. Expansion is the greatest difficulty to overcome in both systems. It is easier in hot water systems because the range of temperature to which the pipes are subject is less than that of steam systems and consequently less range of expansion.

In short runs the expansion can often be taken care of by turning the direction of the pipe line. The most common method of providing for expansion is by means of slip-joints placed in man-holes from 300 to 400 feet apart. One might think that these slip joints would give trouble but as they only move about twice a year they last a long time. There are several in the plant here that have been installed five years or more and not one has troubled so far.

In hot water plants slip-joints are usually used on 6 inch pipes and larger, and U bends on smaller sizes. The American District Steam Co. have what they call a variator to take up expansion where service connections are taken off. These are placed about 100 feet apart and serve two purposes. They care for expansion and outlets are provided on both sides for service connections. Midway between these slip-joints and variators are placed anchors which hold the pipe from moving endwise. Service connections are also provided at these anchors so that by variators and anchors a service can be taken off every 50 feet.

In hot water plants service connections on 4 inch pipe and less are made by cast iron fittings and on larger sizes are usually tapped directly into the pipe. Most water service pipes runs from 3-4 inch to 1 1-4 inch in diameter.

As to the kinds of pipes used in both systems cast iron is the most durable and will last indefinitely. It is not acted upon appreciably by either the water or the condensed steam. Owing to the almost prohibitive cost of cast iron pipe, both systems are usually made of wrought iron pipes with cast iron fittings.

I might say here that the black pipe now on the open market is not wrought iron, but mild steel. It is almost impossible to get wrought iron and one must pay dear for it. Dealers will tell you that it is wrought iron, but if you should put in a heating system look out, for steel pipe will not last long in steam mains. In water mains it is not so bad. Condensed steam will pit a steel pipe in a short time. Good wrought iron will last for fifteen to twenty years in steam and longer in hot water mains.

Both systems must be well insulated so as not to lose the heat and keep the pipes from outside corrosion. Here again the hot water has one advantage, the temperature being lower than that of steam does not require such careful insulation. Again the insulation is not destroyed by the heat. The American District Steam Company have a special log covering for the pipe. A few layers of sheet asbestos is placed around the pipe and then a log of 4 inch white pine tongued and grooved is placed around the pipe. This log is lined with tin so as to reflect the heat, but our experience here has been this tin soon rusts and is then of no value. The outside of this log is covered with pitch and band wires are put around it so that the log can not go to pieces. This is covered with tar paper and dirt. A porous tile is placed underneath the log. The variators and slip-joints are placed in brick boxes with oak plank covers laid over with brick. The manholes are of brick also. Sawdust is put in these places to insulate the pipes. This is one of the most common insulations used on steam systems.

The short system, however, use a box made up of cypress plank and hair felt between the sides and filled with shavings inside.

Hot water systems usually use a box made up of 2 inch cypress plank with air spaces between and shavings treated with crude oil around the pipes as shown on chart No. 2.

It is advisable when possible to do so in steam systems to return the water of condensation to the station. To do this means an additional pipe laid besides the main steam pipe in the trenches. The material of which this pipe is made must be either cast iron or wood. The solvent action of the condensed steam soon eats away steel or even wrought iron. Wood is the most common substance used in this with cast fittings.

The water of condensation never leaves the station in hot water systems so that after the oil is extracted it is again ready for the boilers. This is a great saving where water is purchased from outside parties, and another thing, it is free from boiler scale.

In a steam system a separator is placed in the steam main near the station to extract the oil and water from the steam. Some oil goes on with the steam, but it is not objectionable because it coats the inner sides of the pipe line with oil and corrosion is not so active.

One of the greatest advantages in hot water systems is the storage capacity of heat in the volume of water in the pipes. This fact alone makes this form of heating better adapted to lighting plants, or where there is not an even all day load, than direct steam. The peak of a lighting load is from five to ten p. m. This is just the time of day the least heat is required. In



Fig. 2.

a water plant much of this heat can be stored up during the night in the hot water to be used in the morning from six to 10 o'clock, which is the peak of the heating load. This is one trouble with steam plants of making the electrical load of the station and the peak of the heating load come together. If this cannot be done

there is steam wasted during the electrical peak and live steam must be put into the heating plant during the morning hours. This is not a very economical thing to do.

So long as a station can furnish enough exhaust steam for the heating plant the exhaust is a by-product of the station, but when you begin to turn live steam into the heating plant you commence to make the electrical load a by-product in a direct proportion to the amount of live steam used. To illustrate, suppose a heating plant uses 100 lbs. of live steam per hour in addition to the exhaust steam. This 100 lbs. of steam if passed through the engines would produce about two kilowatt hours of electrical energy, and still do nearly 90 per cent. as much heating as before. Therefore for every 100 lbs. of live steam used in heating we could produce with practically no additional cost 2 kilowatt hours and do practically the same heating as before. This energy could be sold at a very low figure and make a good profit. But! This 100 lbs. of steam should not be sold as exhaust, but as live steam and the cost of producing and delivering it should be computed before it is sold to see at what price it can be sold at a profit. This is one of the greatest stumbling blocks in district heating. All over the country the central station managers throw up their hands with horror when live steam is turned into the heating plant; when as a matter of fact if the price they receive for the steam is more than it costs them to produce and deliver it, there is no need of alarm: but if it is less then, look out. In computing the price at which exhaust heat is sold it should be based largely upon the cost of production for sooner or later live steam will be required.

Where live steam is required on the heating plant it does not make any difference how much back pressure is carried so long as the engines can pull the loads upon them. Many engineers are misled by the amount of power an engine is cut down by having a back pressure. An engine is usually rated at $\frac{1}{4}$ cut off. This $\frac{1}{4}$ cut off gives 4 expansions of the steam. At 150 lbs. boiler pressure and $\frac{1}{4}$ cut off gives a Mean Effective Pressure of 83 lbs. under ordinary conditions of exhausting into the atmosphere. If the engine had 10 lbs. back pressure, which should be an extreme case, it would take steam less than 1-3 stroke or a little more than 3 expansions. Thus we see that by having a back pressure of 10 lbs. it cuts the *rated* horse power of the engine 22.2% or nearly one expansion of steam. Take the case where the engine takes steam full stroke it would have a M. E. P. with atmospheric exhaust of 148 lbs. or an engine under these conditions is capable of pulling 78% more than its rating. Now put 10 lbs. back pressure on this engine and when it takes steam full stroke it will have a M. E. P. of 138 lbs.

which is 65% more than its rated capacity or 13% less than what it is capable of doing.

Therefore an engine rated at $\frac{1}{4}$ cut off, on 150 lbs. boiler pressure, and exhausting into the atmosphere is cut down 22.2% of its *rated* power and only 13% of what it is capable of doing in extreme cases by the addition of a back pressure of 10 lbs.

Some one says the engines will take more steam per horse power with a back pressure. When the heating system requires live steam it does not make any difference how many lbs. of steam the engine takes per horse power. Suppose again that 100 lbs. of live steam is required for the heating plant. It makes practically no difference whether 75 lbs. of this goes through the engine and 25 lbs. through the by-pass or 25 lbs. through the engines and 75 lbs. through the by-pass. The cylinder in this case can be looked upon as only an enlargement in the steam pipe, again a back pressure is not so un-economical as is generally supposed because it reduces the cylinder condensation.

A compound engine is more economical in its use of steam than a simple engine placed under the same conditions of initial and final pressures. There is some danger of bursting the low pressure cylinder with a high back pressure where it will not effect a simple engine.

In hot water plants there is no need of a back pressure, in fact they can run condensing by passing the steam first through the heater on its way to the condenser. It is possible to have the water in the heater at 160° F. and a vacuum of about 18 inches on the engines. This condensation can be used over again in the boilers and not lost in the sewers as is usually done in steam plants. The temperature of the water can be varied to suit the outside temperature. Water leaving the station at 200° will have a loss of 1° per 1000 feet traveled. When the water goes out and comes back it loses from 30°-50°, depending upon the outside temperature of the air.

Fuel economizers can be used to heat the water for the mains. Some plants pass the water through old boilers in place of using live steam.

When the water is circulated in the mains by means of pumps no need be paid to the grade of pipes on closed systems. A closed system is one in which no part is open to the atmosphere. In closed systems the pumps require less steam to force the water. The exhaust from the pumps is used in heating the water so there is no loss in this when live steam is required.

Hot water is not adapted to tall buildings or a hilly city on account of the hydraulic head of water which makes an objectionable pressure on all the system and in case of a broken pipe or radiator may prove a troublesome thing.

In small plants hot water is said to be about 20% cheaper in coal than steam and is certainly more convenient.

Having given you some of the advantages and disadvantages of both systems we shall now take up an assumed city and see whether or not a plant is advisable. The first and last question to ask is: will it pay? This is a very simple little question to ask but the answer is a difficult one.

About the first thing to do is to gather all the data possible from the particular town in which the plant is to be located; survey the city and see the feasibility of a plant; get the sizes and number of business houses and residences, etc., that will take the heat and are not too badly scattered or too far from the plant; get the hours the plant will run and the time of day the peak load is on the station; get the amount of exhaust steam it produces per day, the amount of coal used per year, etc., then find the amount of steam required for the heating plant, etc.

The following data may be of service to you in answering the question "will it pay?"

Mr. William D. Marks in his *Finances of Gas and Electricity* states that for water systems one ton of coal will heat on an average, 1600 cubic feet of space per season and return \$5.30 at 1-3c. per cubic foot heated.

3-4 of the coal burned by a lighting station during the year and 2-3 for trolley systems is available for heating purposes.

Assume a plant which uses 1700 tons of coal per year of which 1200 are available for heating purposes. This will heat 2,000,000 cubic feet of space and would return \$6,000.00 as gross earnings per season. Assuming this to be 15% of the safe investment, one could put \$45,000.00 into a heating plant. The above figures are based on exhaust only and if live steam is used the cut off production and delivery must be considered.

Mr. Marks says that an average residence of 40,000 cu. ft. of space and at 1-3c per cu. ft. yields \$132.00 and requires 25 tons of slack coal per season.

The exhaust of an engine lighting four houses of 160,000 cu. ft. will warm one of 40,000 cu. ft.

In a hot water plant he says having 200 houses and the greatest distance from the station is 3-4 mile the largest sized pipe in 6 inches and average 4 inches. The pumps force the water at 40-60 lbs. and at a temp. from 170°-212°. Each house on an average requiring 2 cu. ft. of circulating water per minute. Now under these conditions it is stated that the average loss of heat in the ground is 15 to 20%. The total radiation on this plant is 175,000 sq. ft. or 22 sq. ft. per 1000 cu. ft. space.

On an average steam requires 15 sq. ft. of radiation and hot water 21 for every 1000 cu. ft. of space heated.

At Topeka, Kansas 1 sq. ft. of radiation is said to condense 360 lbs. of steam per season. This at 50c. per 1000 lbs. of condensation would yield 18c. The plant here averages about 25c. per sq. ft. per season which is equivalent to about \$3.00 per 1000 cu. ft. of space heated per season. 1 sq. ft. of steam radiation will condense 1-3 lbs. of steam per hour as a maximum and 0.12 as an average.

Each boiler horsepower will supply from 70-100 feet of radiation.

Average conditions are of little value to apply in a special case. Allowance of from 50-100% either way should be assumed.

Heating plants if properly installed and managed usually make enough to pay for the coal and a fair interest on the investment.

I shall now give you some figures on the cost per linear foot of steam mains. These prices will give a general idea but allowance should be made for the advance cost of labor and material in the past few years.

The system that is used here in Lincoln is known as the American District Steam Co. System. The following figures are the approximate costs of such a plant without ditching per linear foot:

| Size of pipes. | Variator Construction. | Slip Joint Construction. |
|----------------|------------------------|--------------------------|
| 3 in. | \$2.75 | 10% less |
| 5 in. | 3.35 | \$3.00 |
| 6 in. | 3.80 | 3.38 |
| 7 in. | 4.35 | 3.87 |
| 10 in. | 6.30 | 5.60 |
| 12 in. | 7.40 | 7.00 |
| 14 in. | 9.80 | 8.70 |
| 20 in. | 23.50 | 10% less |

The cost of trenches for the above varies with the size of pipes and kinds of streets the pipes pass thru whether dirt street, macadam, brick, stone, cement blocks, or asphalt, the trench cost ranges in various classes of work as above from 20c. to \$1.60 per linear foot.

The short system for steam pipes consists of plank with wool felt between and filled with shavings around the pipe similar to figure No. 2 for hot water mains. Slip joints in man holes every 400 feet complete for laying ditching, etc., in dirt street and having service openings every 50 feet:

| Size Pipe. | Price per linear foot. |
|------------|------------------------|
| 5 in. | \$2.20 |
| 6 in. | 3.20 |
| 7 in. | 4.30 |
| 10 in. | 6.00 |
| 12 in. | 6.75 |
| 14 in. | 8.50 |

I have not been able to find anything practical bearing directly on the relative sizes of pipes for the same carrying capacity of steam and hot water. Let us look at the fundamental principles a moment. Hot water on its journey to the buildings loses about 40° in temperature this is about 40 British Thermal Units per pound of water. A cubic foot of water at this temperature weighs 60 lbs. Then one cubic foot of water has $60 \times 40 = 2400$ B. T. Us of heat to deliver on its journey. Now steam at 5 lbs. gauge pressure has 955 B. T. Us per pound and occupies 19.5 cu. feet of space. One cubic foot of steam carries 49 B. T. Us of heat on its journey to the buildings.

Then one cu. foot of water carries 2400 B. T. Us of heat and one cubic foot of steam carries 49 B. T. Us of heat; Therefore steam would have to travel 48 times as fast as water to carry the same amount of heat. Steam at 5 lbs. pressure travels about 4000 feet per minute and assume water at 160 feet per minute, which is a very low rate indeed for water, then the rates of travel would be 2 to 1 instead of 48 to 1. In this case the steam pipes would have to be twice as large as water pipes for the same capacity. In water systems two pipes are required so that the combined ratio of sizes of pipes would be the same.

On January 30, 1907, the temperature was five degrees below zero. I took some readings of pressures on the various parts of the mains of the system here to get the drop due to friction. A 6 inch pipe carrying 26,000 feet of radiation had a drop of $2\frac{1}{2}$ lbs. in 300 feet.

A 16 inch pipe carrying approximately 100,000 feet of radiation had a drop of $1\frac{1}{2}$ lbs. in 1230 feet. The greatest range of pressure was $11\frac{1}{2}$ lbs. to 2 lbs., or a drop of $9\frac{1}{2}$ lbs. to the most distant point on the system. This great range of pressure is in part due to the fact that a large percentage of the business is on a small pipe farthest away from the station. If the load was properly distributed or the pipes installed to fit the load no such ranges would be required. This is one more trouble in steam systems of getting the pipes correctly proportioned because you can't always tell where the most business will come from as conditions are constantly changing.

By referring to chart No. 3 one can get an idea of the variable load as the temperature varies. The amount of heat re-

DISTRICT HEATING.

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Fig. 3.

quired depends upon three factors temperature, humidity and wind. The last two are of minor importance to the temperature. In these curves the readings were taken every week as shown. There is a striking resemblance between the temperature and consumption curves. The loss curve however does not seem to be governed by the temperature. It is about uniform regardless of temperature and the amount of heat used. In fact when the most heat was used the apparent loss in the pipes was loss. This is due to the live steam used which being superheated re-evaporated some of the water in the mains.

The percentage of loss to the amount of steam carried varied from 6.4% to 25% during the time this test was run, which was from October 9, 1905 to March 27, 1906. The average loss during this time was 10.4%. The loss from March 27 to May 15th was 47%. The loss in May was over 100%. These figures may seem confusing but when you consider that the loss in the streets for December and May is about the same but the amount of heat used in May is very small. It did not make any difference in the economy of the system whether this steam was lost in the streets or exhausted into the air. In fact it was economy because it gave one more exhaust pipe to the engines so to speak and the back pressure was less than when this valve was closed. The average loss from October 9 to May 15 was 11.7%.

The American District Steam Co. state that they find this loss for a number of plants to be about 5%. This is where the plant is used to nearly capacity and the season is from October 15 to April 15. They state that the loss per square foot of pipe area of the mains is .04 lbs. per hour. I found it to be .05 for the time the test was run.

RAILROAD LOCATION.

M. W. Ensign, Locating Engineer, C. B. & Q. R. R. Lines West of Missouri River.

Thanking you for the honor conferred by a member of your editorial staff in requesting me to write an article on railroad location from such information as I had gained by many years of field service in all kinds of country, I take pleasure in complying as briefly as possible.

If the work to be undertaken is of considerable extent the personnel of the party should be as follows: A chief, transitman, leveler, topographer, draughtsman, two chainmen, rodman, assistant to topographer, rear flagman, stakeman, one or more axmen depending upon amount of timber country, cook and two or three teamsters according to the number of teams.

The outfit will consist of three pyramid tents, 16x16 with five feet walls and flies, four pairs six-pound woolen blankets to each man with double tarpaulins of twelve ounce duck for covers, heating stove, a six hole steel range, complete cooking and dining outfits, three good teams and wagons, one saddle horse, instruments, tools and other paraphernalia necessary for comfort and to prosecute the work economically. A small wall tent for storing supplies weighs but little and is very useful. The commissary should consist of the best variety of substantial foods obtainable and a moderate amount of delicacies in the way of the best brands of canned fruits for field lunches and evaporated or fresh fruits for table use.

With good supplies and a neat, competent cook to prepare them for the table, you will generally have a satisfied party. Poor supplies are unsatisfactory and expensive and an untidy cook only good to be gotten rid of.

Even in the best settled country I have found the camp much more satisfactory than stopping at farm houses and hotels as this gives members of the party a home of their own. It is interesting and pleasing to note the care usually taken by members of the party to make camp homelike. Such manners as are observed in every good home should be practiced and insisted upon by the chief, especially at meals. I do not know of any form of living that so quickly brings out the best and worst traits of human character, the best soon predominating when guided by a competent chief.

It will not be necessary to go into detail regarding personal qualifications of each member of the party, as what applies

to the chief will in a measure do so to all, since each at some future time hopes to fill an equally desirable position.

To fill the place successfully the chief must be a man in the broadest sense of the word and of more than ordinary executive ability. He must be temperate in all ways, strictly honest, courteous, remembering that all have rights which must be respected, a strict but kind disciplinarian, so winning the respect and confidence of his men that they will consider it a pleasure to do their best under all circumstances. He must be a leader, not driver, since the class of men suitable for the work are usually too intelligent to stand driving. He must be competent to do all kinds of work in detail from currying a mule to solving intricate trigonometrical problems. He must always be on the alert, knowing from personal observations that each man is properly performing the duties assigned to him. With these qualifications he will be able to instill into each member of the party a desire for gentlemanly conduct, neatness and regularity in everything connected with camp life and work in the field.

I have found the most satisfactory field hours are to start from camp promptly at seven A. M. reach camp and be ready for supper at half past six P. M. having had an hour for lunch in the field. After supper there is an hour's work for the transitman, leveler, topographer and draughtsman and chief. The chief's work is never done.

Before starting on a survey the chief should be furnished with such maps and reconnoissance notes of the country to be traversed as are available. These will give him approximate ideas of sharpest curvature and maximum grades to be used, these to be accurately determined by a reconnoissance preliminary run over a freight division. This survey which should be the first done will also determine where it may be desirable to introduce helper grades. Without this information valuable time is apt to be lost from having assumed the maximum grade allowable, a few hundredths too high or low, this being especially true where long maximum planes will be encountered. In these days of low freight rates desired by the public and big dividends by owners of the railroad, the operating department will not be entirely satisfied unless the locator is able to show a down hill pull for all loads.

With data secured by the reconnoissance preliminary as a base, determine by preliminaries every possible feature of the country that will affect placing finished location. The chief should never allow himself to tire of running development lines that show accurately the country. Besides running lines that seem to him necessary he should have each member of his party studying the country and giving him the result of their observations. He will meet a great many outsiders full of advice

that they are anxious to give him. Quite likely they have an ax of their own to grind; however their information may be useful, so listen to what they have to offer thanking them and telling them respectfully in the fewest possible words why their plan is impracticable, if so. Remember that with an inquiring management a great many questions will be asked which can be most satisfactorily answered by a line, profile and estimate. It is very displeasing after days of hard labor to have someone ask a question the answer to which will upset all the well laid plans of the chief, however good his judgment, unless he has often looked at the problem through other peoples eyes. A capable management will never find fault with expenses incurred in surveys when valuable information is gained, negative information often being more valuable than positive. We frequently meet locaters who claim to be able to place a suitable line with few or no preliminaries. Such men are like those who never make mistakes, unsafe to tie to.

In the field especially on preliminary work, the chief needs to supply himself with suitable pocket instruments for taking approximate grade levels and direction, then keep in advance of the party in order to lay these lines to best secure with least work topographical features that will control placing the location. We often find men finally obtaining good results who do so at unnecessary expense by not being active enough in examination of the country ahead of the field party. It is on this work that the saddle horse is most valuable allowing the chief to get over more country and still be in touch with the party.

As the speed and accuracy of the location depends upon accuracy of information secured by development lines in the field and mapped, the work cannot be done too carefully. About the first instructions I received in my school days were to do the preliminary work with care then the finishing correctly would be easy. It is annoying to find after planning a line and placing it in the field, that inaccurate work on development lines puts your location entirely away from where you had planned. I have often known of lines showing accuracy enough so that a circuit of fifty miles gave latitude and departures that closed within a few feet, the courses often checking to the minute.

In rough country I find that slopes taken along the direction of drainage and ridges give better results than when taken at right angle to the line, also that more territory can be covered with the same amount of work, to do this the topographer should in addition to slope level have a compass having at least a two and one-half inch needle with which to take courses of slope lines. Where very steep, take slopes along the bottom of ravine and crest of ridges, with well defined bottoms and flat tables between. Take slopes along drainage line then foot and top of

steepest slopes, and where tables are wide at intermediate points often enough to secure data for locating accurately the slope on a map. I find best results as a whole are obtained by referring slopes to the ground elevation at station from which slopes are taken and recording in note book as so many feet above or below ground at that station with distance right or left of it, afterwards determining location of ten foot contours in the office. To secure ten foot contour intervals in the field means that the topography party must be a day behind and have the annoyance of carrying a profile in the field with it. While saving the draughtsman time this is unsatisfactory requiring extra transportation facilities and dividing the party. To keep all interested, I find it well to have the field party bunched as much as possible for when one part is much behind it soon becomes discouraged and drags. Although extremely accurate topographical work can be secured by use of plane table, doing platting in the field the numerous drawbacks to its use more than offset the accuracy gained.

Even in rough country topographical features should be accurately located over a strip of country five hundred feet each side of the center line, while the trend of streams and objects of interest such as houses and prominent points should be sketched in and approximately located for at least one-fourth mile away. For locating distant objects where considerable accuracy is desirable, stadia measurements give good results and can be obtained by a transit having stadia wire; or small horizontal angles, with a short horizontal distance measured at right angle to line desired being measured, taken from point to be located.

Usually books for recording topographical notes are ruled with small squares. Each one of these should represent a distance of 50 feet each way both vertical and horizontal. Along the center line of the page station numbers should be marked every second line, the left hand page being used to record slopes; the right hand, trend of streams, buildings and outline topography, the distance out being shown by number of squares from center line drawn vertically across the page. Any object located beyond limits of page will have the distance written out, the use of two pages saves complicating notes.

There should always be two and usually three maps made, a 5,000 foot scale map showing all lines run, with elevations at controlling points, drainage line of principal streams and land line. This is for general use and the most valuable map the chief has for determining in a general way the location of the line. A larger scale map becomes unwieldy. In rough country a 400 foot scale map for detail work will be required. This should show accurately all information secured, so the location can be projected and profile made from which it is possible to make

estimates in planning location. The third map will be 1000 feet to an inch for general office use and during construction. This must show all land lines, improvements to property, roads, drainage lines, areas under 640 acres and prominent bluffs hatched in.

In flat country this map can take the place of the 400 foot scale map.

All lines should be platted by latitude and departure calculated independently by the transitman and draughtsman. No other method gives satisfactory results.

After the lines are platted, all buildings, roads, improvements and streams should be put on the map then contours for each ten foot interval carefully and clearly mapped showing the one hundred foot intervals by a slightly heavier line. Crossing lines run by contour intervals should always be located from profile of line. From topographers slope notes ten foot contours can be obtained either graphically or by calculation. If graphically, flat slopes from stations given, on preliminary profile using blue lines for right hand slopes and red lines for left hand. This method has the advantage of being quick and the draughtsman has the profile of line and slopes before him, but when slopes are taken close together it is sometimes confusing. In calculating rule a note book with vertical lines one-third of an inch each side of the center line, recording the station number on each second horizontal line and the surface elevation at points from which slopes were taken. On each side of this show the ten foot contours with distance from center line. I like this method best as it gives a compact record of the work. The draughtsman should be sure all information secured is put on the map as there is never too much.

With our preliminary work completed and mapped, the proposed location must be carefully drawn on the working map making profile of the projected location from the map and calculating to be sure it is right. From this projection accurate notes must be figured for the line to be run. Here your latitude and departures will be useful and save depending entirely upon scaling notes from the map. Where the country is comparatively smooth the final location stakes can safely be driven, but in rough country it is better to run a trial location with preliminary stakes and unspiralized curves as slight changes are liable to be needed to obtain the cheapest and best line. The final location should usually be marked with stakes one inch thick, two inches wide, sixteen inches long, one half the length being driven in the ground. Bench marks for permanent elevation should be located at least each 1000 feet, preferably on permanent objects such as roots of trees and corners of house walls. If these cannot be had, use good strong hubs with guard stakes.

All 2° or sharper curves must be spiralized with transition curves as long as the distance required to elevate out side rail in passing from tangent to a circular curve, usually two hundred feet. The number of chords in transition curve should equal the degree of circular curve spiralized. Thus a four degree curve will have for a two hundred foot transition four fifty foot chords. Remember that starting from the tangent the first chord deflection will have as many minutes as there are ten foot parts in that chord which would be five minutes for a fifty foot chord. Deflect for the first chord the number of minutes given and for each succeeding chord this angle multiplied by the chord number in a 4° curve with a 200 foot transition curve we would have four chords, deflection to the first five minutes, fourth or beginning of circular curve 5x16 or 80 minutes, with transit set at P. C. of circular curve and backsight on beginning of transition curve deflect double angle from beginning of transition curve to this point to get on tangent; then run circular curve by usual method. To run transition curve from circular curve to tangent, calculate what the deflection angle for a circular curve will be for distance to point desired to set, then reduce that by the deflection for transition curve the same distance figuring from tangent point, thus for third point on a four degree with two hundred feet transition, we would have for 4° curve 150 feet 180 minutes transition curve to third point, 45 minutes leaving 135 minutes deflection from tangent at end of circular curve to set point three from circular curve. In all cases total transition curve angle will be equal half the length of that curve multiplied by degree of circular curve.

Given the angle and the degree of curve to be spiraled to find semitangent to locate beginning and first obtain shift of curve due to spiral, add this to the length of radius of curve to be spiralized, calculate semitangent of curve with this lengthen radius and add to it half length of transition curve to obtain points from which to start and end transition curve. The shift can be quickly obtained by Professor Green's formula which is:

$$\frac{8 L^2 D}{1,100,000} \quad D = \text{Degree of Curve.}$$

$$L = \text{Length of Spiral.}$$

I have taken considerable space describing this method of running transition curves as it is simple, rapid and sufficiently accurate for the work to which applied.

On location care must be taken to tie in all land lines and improvements within 500 feet with accuracy. Run out all drainage under 640 acres where small culverts or pipe openings can be used. Openings that will eventually be large culverts

can usually be filled at first by temporary bridges and areas run out by maintenance engineers.

On the 1000 foot scale map and profile of location show everything that will be of use in construction remembering too much information cannot be given so long as it is done with clearness.

Now for a few words on values: There are so many text books on these and various scientific problems of location, what I could add would do little to enlarge your knowledge in that direction.

Values will be determined by the probable traffic of the line. We ordinarily get them too low. The usual method of obtaining them is by the train mile. While to me this seems very indefinite and should be replaced by the car or ton mile, I have thus far been unable to get accurately such data, so content myself with what can be had.

It is generally conceded that we can afford to spend \$7.50 per degree of curve thrown out for each train over the curve, that is to say if you have twenty trains per day over the curve you can spend \$150.00 per degree of curve saved.

While I think most authors do not consider a curve thrown out regardless of angle, of any value, I find from partial records of accidents undoubtedly due to the curve, that a low estimate for a curve thrown out above angle saved would be \$1,000.00. In case of blind curves and those sharper than safe to run over at high speed \$10,000.00 would be a small expense to incur in eliminating them. We have had numerous cases within the last few months, both in America and Europe will prove this.

Distance saved has many conditions to be considered such as revenue lost, especially in passenger earnings in non-competitive territory and greater expense and no more revenue where your competition has the shorter line. On the assumption that maximum grades will be the same by either line, \$11.00 per foot per train would be high enough.

Using Wellington's method of figuring for rise and fall, I find for grades steeper than .05%, forty (40) dollars per foot of hill per train and \$25.00 per foot on the same basis for grades below .05%. The basis of this figuring should lie, for at least the greater items of increased expense, one ton raised one foot. Accurate data along this line I find hard to secure.

Equations on grades due to curvature depends greatly on condition of rolling stock as regards bearings between trucks and car body. I know of one instance where experiments were made with overloaded bad order cars where reduction was nearly 0.1 foot per degree of curve, other experiments have shown as low as 0.06 feet per degree. Some engineers figure as low as

0.03 feet per degree. While I have always used as high as 0.05 feet per degree of curve with fair results, I am satisfied that with usual condition of rolling stock 0.075 feet per degree would be better. This is especially true where the curve is long, and short tangents between curves.

I hope that some of the points touched on will be of value to the young engineers who may be called upon in the future to do location work.

INDUCTION MOTOR APPLICATIONS.

A. E. Hibner, Westinghouse Electric and Mfg. Co.; Pittsburg, Pa.

A great many articles have been written during the past year on the induction motor, most of them dealing with its electrical characteristics from a theoretical standpoint. This article will deal with the induction motor more from a commercial point of view, and a few of the more common applications will be mentioned.

Factories building induction motors are, as a rule, very far behind in their orders, especially in the more common speeds. This increased demand for this type of motor is probably due to a great extent, to the efforts of the central stations. The central stations are beginning to realize that, to get a maximum return on their investment, they must operate their plants at as nearly a constant load as possible twenty-four hours a day. This, of course, means a power load during the daytime. The central stations are, therefore, sending out solicitors whose business is to get small factories and shops to install motors for driving their machinery and are prepared to offer low rates for this class of service. Large central stations usually carry in stock, in limited quantities, motors of all sizes suitable for the particular characteristics of their circuits.

It might be of interest to outline the different types of induction motors that are being manufactured to meet the various requirements of the consumer. Complete lines of these motors have been designed from one-half horse power up to five hundred horse power, and can be obtained as high as two thousand horse power. Motors of sixty and twenty-five cycle circuits, two or three-phase, and of 100, 200 or 400-volts, are regularly carried in stock from one-half to seventy-five horse power, where the factories are able to keep up with the demand. Motors above twenty or thirty horse power are also designed to operate on any voltage up to three thousand but are not as a rule carried in stock for immediate shipment. Speeds for stock motors for sixty cycle circuits are 1700 and 1120-R. P. M. for the smaller sizes and 1120, 850 and 690-R. P. M. for the larger sizes. For twenty-five cycle circuits the standard speeds are 710 and 480-R. P. M.

For slower speeds than those above given, a complete line of back-geared motors has been designed. By this means slow speeds can be obtained at a much less expense than could be done by any electrical means. These back-geared motors consist

Fig. 1

of a standard motor furnished with special brackets carrying a counter shaft and bearings, the counter shaft being geared to the motor shaft. With this system, almost any speed can be obtained for a given horse power. For example,—take a twenty-horse power, four pole, sixty cycle motor. The full load speed will be about 1700-R. P. M. By using back geared parts, a counter shaft speed from 425 to 225-R. P. M. can be obtained. With a six pole motor, running at full load speed of 1120-R. P. M., a counter shaft speed of 280 to 150-R. P. M. is possible; and with an eight pole motor with a full load speed of 850-R. P. M., counter shaft speeds from 210 to 115-R. P. M. are obtained. Motors equipped with back geared parts cost very little more than standard motors, yet slow speeds can be obtained very efficiently by this method. Either the standard or back geared motor can be arranged for wall or ceiling suspension.

In addition to the back geared motors there are on the market complete lines of vertical motors. These motors have the same electrical characteristics as the horizontal motors, but have their shafts in a vertical instead of horizontal position. The weight of this rotating part is usually carried by a ball thrust bearing, running in an oil bath. These motors, in addition to the ordinary open type, are also built totally enclosed for driving sinking pumps. These motors can be submerged in water without injury, but cannot be operated under water. Vertical motors are, of course, designed primarily for direct connection to pumps or similar apparatus and are not suitable for driving machinery by belting.

All of these motors are designed with the squirrel cage secondary, but there is also a type of motor having a wire wound secondary. This type of motor is used almost altogether in the large sizes, where the size of the motor is large in comparison with the generating plant, or where it is necessary to start heavy loads and bring them up to speed. The chief characteristic of this type of motor is small starting current required to get full load torque in starting; this condition being obtained by inserting resistance in the secondary circuit. The wound secondary also furnishes a means of varying the speed, the speed depending upon the amount of secondary resistance. This motor, however, is not a variable speed motor in the strict sense of the word; that is, the horse power output is not constant over the entire range of speed, as in the case of the direct current variable speed motor. The horse power output in this motor depends upon the speed, the slow speeds being obtained at a sacrifice of horse power.

The above outlines in brief the various types of induction motors that are being built every day by electrical manufacturers. It is seen that the induction motor can replace the direct current

. Fig. 2.

motor for all ordinary classes of service and has the advantage of simplicity and rugged construction, the induction motor having no commutator to collect dirt and give trouble. The induction motor without a doubt requires less attention than any other moving piece of electrical machinery. This does not mean that no attention whatever is required. Salesmen have been known to make the statement that induction motors require absolutely no attention whatever. Such a statement, of course, is not true and if followed out by the customer, ends in the burning out of the motor winding or bearings. The motor should be kept free from dirt and the bearings supplied with plenty of clean oil at frequent intervals. Instances have been known where the motor has been neglected and the dirt accumulated to such an extent that the motor could not be started. Numerous cases have been known where bearings were burned out simply by neglecting to supply the bearings with oil at frequent intervals. While on the

subject of troubles, a common one with a newly installed motor might be mentioned; namely, the blowing of the main line fuses when the motor is started. Induction motors of any size are usually protected by two sets of fuses. One set is just large enough to carry full load current and is automatically cut out of circuit in starting. The other set is placed in the main supply

circuit and must be able to carry about three times the full load current. Customers, in installing a new motor, will very frequently place fuses in the main circuit which are just large enough to carry full load current, and they are very much sur-

prised when the fuses are blown as soon as the motor is started. A great deal of trouble and expense to the customer can be saved by a little investigation in such a case and by the use of larger fuses in the main circuit.

One of the most common uses for induction motors is prime mover in a motor generator set. These sets are used a great deal as exciters for alternators and for charging storage batteries.

For this kind of work the induction motor can be designed for maximum efficiency. These sets are usually started without a load on the generator and very little starting torque is required. The squirrel cage type of secondary is generally used and the motor is designed for a minimum slip, thus giving a maximum efficiency. Good starting torque requires a certain amount of secondary resistance, which means a greater full load slip and more copper loss. It might be mentioned that the amount of secondary resistance in the squirrel cage type of secondary is controlled by the composition and area of the short circuiting or end rings. Under the same class of service as the motor generator set would come motor driven fans, blowers and air compressors. In the case of the air compressor, there is some times furnished with the motor an automatic controller, which starts the motor when the air pressure drops to a certain point and stops the motor again when the pressure has been raised to

a certain limit. The same scheme can also be used for hydraulic work. This system makes a very economical set, as all expense ceases when the motor is stopped. As an example of the use of induction motors for driving centrifugal pumps, the 2000 H P motors, supplying water for the cascades at the St. Louis Exposition, might be mentioned.

Certain classes of machine tools can be operated to advantage by induction motors. Among these are spindle drills, punches, slotters and planers. With these kinds of machines, the motor is usually mounted directly on the frame of the machine and is either directly connected or geared to the mechanism of the machine. For such class of service, where there are heavy reciprocating parts, the motor is equipped with a flywheel to relieve the motor from the strains, due to the reversal of the planer bed or the sudden load in the case of a punch. The induction motor can better stand this class of service than the direct current motor, which tends to spark at the brushes when suddenly subjected to an overload. Furthermore, the induction motor cannot run away should the circuit be accidentally opened, as would the direct current motor should the field circuit be opened. In such a case the motor, and probably the machine which it was driving would be damaged.

While on the subject of machine tools, grinders should not be omitted as induction motors are particularly adapted for this work. Where the direct current motor might be damaged by the dirt and flying particles falling on the commutator from the grindstones, the induction motor would be unaffected, having no parts to be damaged.

In small machine shops and factories, where overhead cranes do not prevent the running of line shafting, group driving is used to a great extent. A great many machines can be driven by one motor in this case and the cost of installation is less than with individual drive for each machine. The motors are usually suspended from the ceiling and are started and stopped by a switch or auto-starter mounted on the side wall or supporting column.

Cranes, hoists and elevators represent another class of service for which induction motors are used to a great extent. In this kind of work, where loads are started and stopped at frequent intervals and carried at reduced speeds, the wound secondary type of motor is universally used. A starting torque of 2 1-2 times full load torque is usually specified where a motor is to operate these types of machines. This type of motor is supplied with slip rings, by means of which resistance can be inserted in the secondary circuit by the use of a suitable controller, usually of the drum type. This type of motor is capable of starting any

Fig. No. 7.

load within its range with a starting current slightly greater than full load running current. The speed is not constant, except with a constant load, and with light loads the speed will be very near the full speed, no matter what notch of the controller the motor is running on. With heavy loads, the speed of the motor depends upon the torque required and the amount of secondary resistance in circuit. For example: Take a 15-H. P., 6-pole, 60-cycle motor starting a load requiring a torque of 60-lbs. On the first notch of the controller the motor will not develop sufficient torque to start the load. On going to the second notch of the controller, the load will start and be brought to a speed of 400-R. P. M., the motor developing about 5-H. P. On the third notch the speed will increase to 750-R. P. M. and the horse power developed to 8.5; each succeeding notch means an increase in the speed and horse power, until finally the secondary is short circuited when the speed is about 1100-R. P. M. and the motor is developing 15.5-H. P. Motors for this class of work are usually only given a nominal horse power rating, which means the horse power developed with a certain temperature rise with the secondary short circuited. In selecting a motor for a particular use, a study of the speed torque curves should be made in order to arrive at the proper size of motor.

Besides the special cases given above, induction motors are used for driving all kinds of wood working machinery, such as band saws, circular saws, planers, etc. Also ice cream freezers, coffee mills, looms, dough mixers, brewery machinery, such as mashers, cookers, brine and beer pumps, and an endless number of machines for similar classes of work. In general, induction motors can be used for all classes of service where a direct current motor could be used with the exception of lathes, where recent developments in high speed tool steel has made it necessary to regulate the speed of the driving motor by very small increments.

One of the most important features of an induction motor to a central station man is its power factor, for the maximum returns are obtained with a given size of generating plant when the power factor is unity. Designers of induction motors realize the disadvantage of a low power factor and design their motors to give the highest power factor consistent with good mechanical design. The power factor of a given motor depends largely upon the air gap and type slot used. Power factors of motors up to seventy-five horsepower will average about 87%, and from this size up will average 92%. The efficiency of motors up to seventy-five horsepower will be about 85% and for the larger sizes will run up as high as 92%.

In conclusion, a few of the electrical characteristics might be mentioned.

The slip varies inversely as the square of the E. M. F.

The slip is directly proportional to the resistance of the secondary.

The torque varies as the square of the applied E. M. F.

To obtain the same horse power when the motor is not run at its designed frequency, the voltage should be changed in proportion to the square root of the change in frequency.

THE VALUE OF ALCOHOL AS A FUEL FOR LAMPS AND INTERNAL COMBUSTION ENGINES.

**By J. B. Davidson, Associate Professor of Agricultural Engineering,
Iowa State College.**

January 1st, 1907, a national law went into effect permitting the withdrawa of alcohol bond free from tax when denaturized, or rendered unfit for use as a beverage by the addition of certain materials repugnant to the taste and smell. This law which was passed by the national Congress in the spring of 1906 brought forth extravagant claims of the value of alcohol for lighting and power purposes. At the present time, there seems to be a general feeling of disappointment inasmuch as it has been discovered that many of the claims set forth by the popular writers of the day were wrong. However, it is a matter of satisfaction that the tax has been removed, as alcohol will find at once an extended use in various industrial arts. In the light of investigation it seems that it will be some time before alcohol will be generally used for the production of light and power.

The Agricultural Engineering Department of the Iowa State College has for some time been conducting experiments to determine the comparative heating value of alcohol and gasoline and the consumption of each in lamps and small engines. The results of these tests will be made public later. The tests recorded in this paper are preliminary tests.

The alcohol used in these experiments was not denaturized and was of 188 proof or 94 per cent purity by volume. It is suggested that the alcohol for fuel purposes be of 90 per cent purity, and hence will be of proportionately lower heating value. The gasoline was the common kind used for fuel for stoves and engines, and was found to have a specific gravity of 0.729. The weight of the alcohol was found to be 6.846 pounds per gallon and that of the gasoline 6.075 pounds per gallon at the standard temperature of 60° F.

To determine the heating value, a Parr Standard Calorimeter was used with an electric igniting device. In order to secure greater accuracy in the weighing of the fuel it was sealed in small glass bulbs of suitable size. These bulbs had capillary tubes attached, and when weighed, filled, sealed and reweighed gave accurately the amount of fuel sealed in the bulb. These bulbs were placed in the calorimeter and broken by compressing

them between the electrodes and the shell wall, with the cap over the mouth of the shell. This method prevented practically all loss by evaporation. It was found almost impractical to handle these volatile liquids in any other way. The principle of the Parr calorimeter consists of igniting from 0.3 to 0.5 gram of fuel in a shell or bomb in the presence of sodium peroxide and a special chemical accelerator, the whole being placed in a suitable bath. Some difficulty was experienced in preventing the alcohol from preigniting and also in igniting the gasoline. No correction was made for the water in the alcohol as care was taken that the heat formed by the union of the water and the sodium peroxide was absorbed before the charge was ignited. The following formula was used in the calculation:

$$\frac{\text{Rise of temp. of bath} \times 0.73 \times (2000 + 134)}{\text{Known weight of fuel (alcohol or gasoline)}} = \text{B. T. U.'s per lb.}$$

The 2000 represents the number of grams of water in bath and 134 the water equivalent of the beaker. The weight of fuel was in grams.

The total heat as indicated by the average of the preliminary tests is as follows:

Alcohol 12146 B. T. U's per lb. or 83151 B. T. U's per gal.

Gasoline 19728 B. T. U's per lb. or 119837 B. T. U's per gal.

The above results would indicate in the beginning that alcohol is 31 per cent lower in heating value than gasoline volume for volume. 90 per cent alcohol would be proportionately lower or about 35 per cent.

LAMP TESTS.

The lamps used in these tests were of the overhead generator type using a mantle. The fuel was passed over the flame and converted into gas by the heat of the flame. The gas was then mixed with air and conveyed to the bottom of the burner then up thru a gauge into the mantle where combustion took place. See Figs. 1 and 2. The candle power was measured in a horizontal direction with a standard Reichsanstalt photometer fitted with a revolving "flicker" screen to blend the lights and overcome differences in color.

All of the above tests were checked by a second test for the same length of time. It was noted that economy depends largely upon the adjustment of the lamp. This adjustment consists in varying the size of the hole in the gas nozzle and the amount of air mixed with the gas. One striking advantage to be noted in the use of alcohol was that it was impossible to smoke the mantle regardless of the mixture. Taking into account the best of these tests, we would believe that alcohol has but 52 per cent of the lighting value of gasoline or one gallon equals 1.92 gallons of alcohol.

Fig. 1.

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Fig. 2

| Lamp | Fuel Used | Duration of Tests | Amount of Fuel Used Pounds | Average Candle Power Developed | Candle power Hours per Gallon |
|-------|-----------|-------------------|----------------------------|--------------------------------|-------------------------------|
| No. 1 | Gasoline | 3 Hrs. | 0.31 | 51.2 | 2948 |
| No. 1 | Alcohol | 2 Hrs. | 0.53 | 63.05 | 1571 |
| No. 2 | Gasoline | 2 Hrs. | 0.245 | 65.5 | 3180 |
| No. 2 | Alcohol | 2 Hrs. | .625 | 87.8 | 1657 |

ENGINE TESTS.

The preliminary engine tests consisted in operating an engine designed for gasoline with both alcohol and gasoline to determine the fuel consumption per brake horse power with each fuel. It was found necessary to start the engine with gasoline in each case. The engine could not be started with alcohol except with difficulty. No difficulty was met with in operating engine with alcohol after having been warmed up provided the jacket water was kept at a reasonable high temperature.

In changing from gasoline to alcohol it was found necessary to open the feed valve in order to secure a good indicator card.

No attempt was made to heat the air before entering the carburetor.

The indicated horse power was obtained with a Schaefer and Budenburg gas engine indicator. The cards were integrated with an Amslers planimeter.

ENGINE DATA. Engine manufactured by Lennox Machine Co., Marshalltown, Iowa. Of the four-cycle type and cooled with water from College main.

Diameter cylinder 7 inches. Length of stroke 10 inches.
Rated at 8 H. P.

| TEST NO | TIME | KIND OF FUEL | TEMP. OF JACKET WATER | M E P. | I H P. | B H P. | R P M. | EXPLOS. PER MIN. |
|---------|------|--------------|-----------------------|--------|--------|--------|--------|------------------|
| 1 | 30 | Gasoline | 198 | 85.6 | 11.7 | 8.66 | 304 | 140.6 |
| 2 | | | 146 | 87.75 | 11.65 | 8.6 | 304 | 136. |
| 3 | | | | | | | | |
| 4 | | Alcohol | 212 | 85.8 | 11.6 | 8.6 | 306.5 | 139.4 |
| 5 | | | 212 | 84.75 | 11.92 | 8.65 | 306.2 | 139.8 |
| 6 | | | | | | | | |

| COMPRESSION | | POUNDS of | | GALONS per | |
|-------------|----|-----------|--|---------------|--|
| ressure. | | Fuel Used | | B. H. P. Hour | |
| 1 | 46 | 3.74 | | .1422 | |
| 2 | 46 | 3.71 | | .142 | |
| 3 | | | | | |
| 4 | 46 | 6.88 | | .2055 | |
| 5 | 46 | 6.33 | | .214 | |
| 6 | | | | | |

Gasoline was used in above tests weighed 6.17 pounds per gallon. The alcohol was of 94 per cent purity as in previous tests. The engine was new and gave a rather low mechanical efficiency.

The above tests seem to indicate that about 40 per cent more alcohol is required to produce the same amount of power as gasoline.

Effect of Compression. The theory has been advanced that the consumption of alcohol can be lowered to that of gasoline in a special designed engine by increasing the compression pressure thus raising the thermal efficiency. No doubt this can be done and preignition prevented by adding water to the alcohol. Such an engine could not be operated with gasoline except for starting. It would also be liable to the many troubles which would

naturally come with high compression pressures in the matter of starting and lubrication. Such engines would also be heavier and would need to be more carefully made to withstand the heavier service.

Production. Denatured alcohol may be purchased at the present time for about twice the cost of gasoline. The question is raised, can alcohol ever be produced to compete with gasoline as a fuel for lighting and power purposes. Alcohol can be manufactured readily from three common crops, corn, the sugar beet and the potato. It was stated before the Committee on Ways and Means of the National House of Representatives in 1906 that one bushel of corn will produce 2.75 gallons of 90 per cent alcohol. M. J. R. Dunstan states that a ton of sugar beet will produce 11 gallons of alcohol and a ton of potatoes will produce 22 gallons. The pulp left from the manufacture of alcohol is of more or less value as a food for stock; the exact value, however, is hard to estimate. Assuming 40 bushels of corn, 16 tons of sugar beet, and 9 tons of potatoes as an average yield per acre, we can estimate that an acre will produce by these crops 110, 176, 198 gallons of alcohol respectively.

Besides these crops, alcohol is at the present time and will to a greater extent in the future be made from by-products from the factory and the farm. It is stated that alcohol may be manufactured now from by-products of the sugar factory at a cost of ten cents per gallon, yet this statement cannot be verified.

It is believed that in time, owing to the increase in the number of internal combustion engines causing an advance in the cost of oil fuels and also perhaps to a decrease in the cost of alcohol, the latter will come into open competition with the former. Just how long this will be we do not know. The special designed engine will, however, be the first to bring the fuels in open competition. The fact that alcohol does not have an unpleasant odor and is more safe to use will give it a field of usefulness where economy is not of the first consideration.

THE RESURVEY OF PUBLIC LANDS.

G. W. Bates, Aast. State Engr., Lincoln, Neb.

The early public land surveys of Nebraska, executed when the greater part of the state was practically unsettled, and was the home of many Indians, who, as the records show, harassed the surveyors to a great extent, were of a very varied character. The modern instruments were almost unknown, and those surveyors who had become accustomed to running all their lines with the needle compass were slow to adopt fully, in practice, the solar attachment invented by Burt.

The use of the compass however, is responsible for every little of the inaccuracies found in the older surveys, as it was the surveyor who slighted the work who has caused most of the trouble found in those parts of the state settled up at during recent years. Those who did their work with good intentions, obtained results which, in general, compare favorably with present day practice and requirements.

It is a well known fact, however, that some of the surveyors did practically no work at all, or ran the lines and left such insufficient monuments to mark their work, that no trace of them can now be found. A large part of Western Nebraska is sand hills, where there are considerable areas without stone or timber, and the problem of securing corner materials of any permanence, at a reasonable cost is now, and certainly was then, a difficult one. In a number of cases it was stated in the field notes that it was impracticable to secure timber for posts, and the corners were therefore established by a mound of earth with pits. Where these mounds were well built, with the pits large and of good shape it is an easy matter to find them at the present time for one who is accustomed to the work, or who endeavors to act with an understanding of the actions of the elements. It is safe to say that no scar made on virgin soil will ever be eliminated by nature, provided the entire surface is not removed by washout or drift.

In a resurvey made last season, in a sand hill country, the greatest difficulty met with was the procuring of suitable corner material. The specifications called for posts of durable material for all township boundaries, and galvanized gas pipe was used for the township corners, with 4 inch white oak posts for all other corners. The original lines were marked with posts of red cedar, and these were found in many places with the markings still legible, after a lapse of thirty-three years. The Manual of instructions requires that there shall be placed in each corner something of an indestructible nature, as brick, stone, or char-

coal. This was done by making small pats of 1 to 2 cement mortar, moulded in muffin tins, and making a cross on them when soft. The sand used was the natural soil.

While corners marked by a mound of earth with pits will remain in such condition that they may be found by the surveyor, it is desirable that the corners be marked in such a way that some part may be plainly visible to anyone. Wood of any kind will last only a comparatively short time, and stone or iron is the only permanent visible mark. The price paid for such surveys prohibits their use where not found within the limits of the work. With a small increase in the rate, stones made of cement could be made and used in the sand hill country.

In a resurvey, or attempt to locate the original corners and lines the first point is to secure, if possible, evidence of the original corners. The position of the original corner is the absolute mark of the lines of government survey, and no new corner should be established until every effort has been made to find this corner. By measuring from known corners the approximate position is first obtained, and then search for traces may be made.

If the corner is located in good sand hill valley soil, with a tough sod, or in soil with more or less clay, the mound will be visible for many years, and the pits will sod over before they entirely fill up, making it an easy matter to locate the corner. If the corner is located in the sand hills, as most of them will be in a sand hill country, where there is no trace of clay in the soil, the mounds will be destroyed by the action of winds and rain until no elevation is left, and the sand from the mound will be shifted back into the pits. It then becomes a question of locating the position of the pits. With a sharp spade the ground should be shaved off, on a plane parallel to the natural surface, in layers not exceeding 1-2 inch. If some trace is not found in five inches, it is usually unnecessary to go deeper, try another spot. When the soil is almost pure sand the first trace found will usually be sand that is whiter than the surrounding soil. When the first trace of lighter color is noticed, the surveyor should go no deeper until he has uncovered the entire outline of the pit, and if it is plain, as is usually the case, he should stop there and not destroy any more of the original evidence than is absolutely necessary. If the outline of the pit is not clear enough to satisfy the surveyor, he should carefully continue, and if it is the pit, traces of ashes and decayed grasses will be found near the bottom. These ashes from prairie fires are about the best evidence that can be found, and as these fires usually occur in the fall, when the prevailing winds are from the north, the accumulation will generally be found much deeper in the north-

erly sides of the pits. The depth of these deposits will, of course, depend on when the first fire occurred after the corner was built, but such fires were so frequent that there will be one or more layers in each pit.

If the soil is a yellow sand, the pit will be filled with grey sand, if the soil is a sandy clay, the pit outline will be in yellowish soil; and, in general, the pit will show a lighter color than the surrounding soil.

When the position of the corner is well within the bed of one of the numerous ponds which fill in the spring and dry up as the season advances, the pit will generally have been washed full of earth, with little if any change of color from the original, but the mound should be found in fair condition. Probably the worst location possible is on the edge of a pond, where the full force of the waves acts, and where it is alternately wet and dry as the seasons change. I have never been able to find a corner in such a location.

If no trace of the desired corner or corners can be found, recourse must be had to the method of proportionate measurements, which is the only legalized method of restoring a lost corner.

If the missing corner is a township corner or a section corner within the boundaries of a township, the method is as follows:

*"A line will first be run connecting the nearest identified original corners on the meridian line, north and south of the missing corner, and a temporary corner will be placed at the proper proportionate distance. This will determine the corner in a north and south direction only.

Next, the nearest original corners on the latitudinal lines will be connected, and a point thereon will be determined in a similar manner."

The first point should then be moved east or west as the case may be, until it is directly north or south of the second point,

*Circular on lost or obliterated corners, General Land Office.

If the missing corner is a $\frac{1}{4}$ section corner, it is to be restored on the line between the adjacent section corners, at a distance from them proportionate to the distances given in the original survey.

If the missing corner is on a standard parallel, guide meridian, or township boundary, it is to be restored on the tangent line between the nearest corners both ways, and at a distance from them proportionate to the distances given in the original survey.

In any case no attention need be paid to the courses of the lines except as a matter of record. They will, in all probability, vary considerably from the original compass courses.

As an example of the first case suppose the corner of sections 7, 8, 17, and 18, to be missing. The nearest corner to the south is the corner of sections 19, 20, 29, and 30, two miles distant. A line is run north from here and the corner of sections 5, 6, 7, and 8, is found at a distance of 239.88 chs. As these meridional lines were given lengths of 80.00 chs. each by the original measurement, the first point will be located 159.92 chains north of the corner of sections 19, 30, 29, and 30. Then a line is run west from the corner of sections 8, 9, 16, and 17, and the corner of sections 7, 12, 13, and 18, on the west boundary of the township is found at 158.62 chains. The length of the line between sections 8 and 17 was originally 79.84 chains, and of the line between sections 7 and 18 was 78.20 chains, a total of 158.04 chains. Therefore, by proportionate measurements, the line between sections 8 and 17 should be given a length of 80.13 chains, and the second point will be located 80.13 chains west of the corner of sections 8, 9, 16, and 17, which point we find to be 14 links north and 17 links west of the first point. The corner will now be restored 17 links west of the first point and 14 links south of the second.

The same procedure would have been used if the nearest corner had been a $\frac{1}{4}$ section corner. Similarly the corner of sections 17, 18, 19, and 20, would have been restored if needed.

In an extended survey where it is desired to restore all missing corners in a township, it will be found best to run the meridional lines and set temporary corners wherever the original cannot be found, then to run the latitudinal lines, noting the intersection with the random meridional lines and the offset to the temporary corners. Then when the length of the latitudinal line is determined, the proportionate distances can be computed, and the proper corrections for the temporary corner or corners found.

So long as the title to all lands the position of which may be affected by the location of any corner, remains with the United States, the General Land Office has the power to change the location of that corner if there are good reasons for the change, but when a deed has been given for any tract the United States no longer has authority to order changes of corners which govern its boundaries.

When it has been decided to resurvey any tract of land, where there are sufficient original corners still in existence to enable the surveyor to restore the missing ones, the claims of landowners are fully protected by the methods of restoring corners outlined above. The patents issued by the Land Office contain the description of the land followed by the words, "According to the notes and plats of the original survey." The

restoration by proportionate measurements locates any corner in its original position as closely as it could be done by anyone but the original surveyor, retracing his own steps. Doubtless some of the older surveys were not executed in exactly the manner shown in the notes, but if the lines were measured at all, they can be proportionately restored.

When, however, it is found that there are no original corners in a township, the rights of the owners of patented land must be respected. If the regular methods of subdivision of a township are followed out, and it is found that the lines so established do not agree with the lines which the settlers have believed to be the proper boundaries of their tracts, they may be deemed to have acquired rights to the land they have occupied. If the new survey is satisfactory to them, and to each of them, they move their lines to agree with it. But if not they can have their lands laid out by special lines called "Claim lines." If more than one party lays claim to any parcel of land, the survey of both claim lines would cause an overlapping, and consequent trouble. While such a case is strictly a matter for the courts to decide, it is the privilege of the surveyor to endeavor to adjust the matter in a way that will satisfy all parties, and so enable the survey to be completed.

Where there are no original corners to be found in a township the regular methods of survey must be followed, and the introduction of claim lines should be avoided if possible as they cut the remaining parcels of land, and introduce fractional lots and irregular tracts. As such cases are liable to occur, it would seem best to have all such work done by regular agents of the General Land Office, working on salary instead of by contractors as is the present custom. The contractor who is working at so much per mile run, does not feel justified in giving days to the adjustment of some matter that will bring him in no return, and yet may be vitally necessary to the best interests of all concerned.



1. 3, LCHX AND
2. FOUNDATIONS.

THE PROPOSED MECHANICAL ENGINEERING BUILDING.

By Prof. C. R. Richards.

The writer has somewhat reluctantly complied with the request of the Editor-in-Chief of the "Blue Print" for a description of the proposed mechanical engineering building, recently authorized by the Board of Regents of the University, for as yet the plans for this building are not definitely formulated and the contemplated floor plans herewith given, which were prepared two or three years ago, may be materially changed upon further study. However, in a general way, these plans will give an idea of the dimensions of the building, with the arrangement of rooms which now seems most desirable.

An examination of the contemplated floor plans of the building will show that it is to be used almost exclusively for laboratory purposes. The front part of the building will be two stories in height, with a basement for the ventilating machinery and the steam piping. The first floor of the main portion of the building will contain the machine shop, the steam and gas engine and hydraulic laboratory, and a large tool room to be used in common by all of the shops and laboratories. Extending to the rear of the main portion of the building are a series of one story rooms with monitor roofs for the foundry, the foundry annex, the forge shop and the toilet and locker room.

The second floor of the front part of the building will contain the wood shop, the lumber storage room, a pattern storage room, a large lecture and assembly room, the fuels and friction laboratory, which for the present at least, will be used as a lecture room for the Professor of Mechanical Engineering, and a drawing room.

In the design of the building particular attention will be paid to the lighting of the various shops and laboratories, a large area of window space will be provided, together with an efficient system of electric lighting for dark days and for night work. It is expected that the building will be heated by direct radiation and ventilated mechanically.

While some of the details of the equipment of the building have already been partially worked out, it is undesirable to attempt to give a description now. This outline will serve, however, to show that the projected building will provide large, well lighted, well ventilated and attractive quarters for the work of the department.

ENGINEERING SOCIETY NOTES.

What The Engineering Society is Doing.

The Engineering society was organized Nov. 27, 1900. Its purpose is to promote engineering research, to draw the engineering students into closer fellowship, to give the engineering departments of the university of Nebraska more prominence, and to provide from time to time pleasing and instructive entertainments for the public.

The present year has been one of the most successful years in the history of the society and the society boasts of a larger membership than ever before. During the present year it has drawn many members from the under class men and they are taking an active interest in the society which speaks well for its future.

The first meeting was held Oct. 10, 1906 and the following officers were elected:

President L. K. Needham; Vice-Pres., A. G. Schrieber; Corresponding Secretary, C. E. Mickey; Recording Secretary, O. N. Munn; Treasurer, O. L. Phillips.

On Feb. 12, 1907, C. G. Hrubeskey was elected Recording Secretary to succeed O. N. Munn. The society has entertained the engineering students at two smokers which were exceptionally well attended. In addition the annual banquet will be held the latter part of April.

Among the speakers who have addressed the society at the regular meetings during the year are Prof. G. R. Chatburn, a lantern lecture on "The San Francisco Earthquake and its Lessons to Builders," Prof. O. V. P. Stout on "The Engineer as a Leader in Industrial Pursuits," Mr. A. R. Swoboda on "The Engineer's Goal," Mr. N. A. Kemmish on "District Heating." This article appears in the current number of the Blue Print, Mr. O. J. Fee on "The Problems of a Superintendent," Mr. T. B. Sears on "The New Burlington Switching Yard."

On April 15 Mr. Walter B. Snow of the B. F. Sturtevant Co. of Boston, Mass., addressed the students upon the "Development of a Manufacturing Plant." Mr. Snow is a pleasing speaker, an author of note and an engineer of acknowledged ability. He recently completed the erection and equipment of the new plant of the B. F. Sturtevant Co.

The program committee are in correspondence with a number of other outside men whom they hope to have here this spring. They have arranged to have an address from Prof Wm. Kent, Dean of the College of Engineering of Syracuse University.

ALUMNI DIRECTORY.

NOTE.—The following is a complete list of the graduates of the University in Engineering courses. There are included a certain number of graduates from other departments who took engineering pursuits after graduation; also some students who left school before graduating and are now engaged in engineering work. The addresses given are believed to be correct to date, March, 1907. The editors will be pleased to receive any corrections or additions to be filed for the use of their successors.

Abel, G. P., B. Sc. C. E. '06. Lincoln, Neb., Eng. Dept. C. B. & Q. R. R.

Akerlund, F. R. B. Hc., M. E. '06. Valley, Neb.

Albers, Juergen, B. Sc., C. E., '93.

Anderson, C. E. B. Sc., E. E. '98. Craig, Neb.

Anderson, E. E., B. Sc., C. E. '05. Lincoln, Neb., Ass't. Supt. of Construction, University of Neb.

Andrew, J. W., Holdredge, Neb. Motive Power Dept., C. B. & Q. R. R.

Arnold, B. J., E. E., '97. Chicago, Ill. Pres. of Arnold Elec. Power Station Co.

Bailey, B. P., '93. Okmulgee, Okla., Electrician.

Barks, F. S., '02. Omaha, Neb., M. E. Dept. U. P. R. R.

Barkley, J. A., B. Sc., E. E., '92. Port Elizabeth Cape Colony, So. Africa.

Bates, G. W., B. Sc., C. E., '05. Lincoln, Neb., Asst. State Engineer.

Bay, Burt, B. Sc., E. E., '06. Phila. Penn. Sales Eng. Westinghouse Mfg. Co.

Beardslee, C. O. Lincoln, Neb., Beardslee, Eng. and Construction Co.

Bedell, C. E., B. Sc., E. E. '00. Pittsburg, Pa. Designing Eng. Westinghouse Mfg. Co.

Belknap, L. J., B. Sc. E. E., '98. St. Louis, Mo., Sales Eng. Wagner Elec. Co.

Benedict, B. W., B. Sc. M. E., '91. Chicago, Ill., Editor of "Railway Master Mechanics."

Benjamin, W. E., B. Sc., C. E., '96. Cheyenne, Wyo. Deputy Co. Clerk.

Bessey, E. A., B. Sc., E. E., '98. Pittsfield, Mass., Expert Electrician Stanley Elec. Co.

Bessey, C. A., B. Sc., E. E., '99. Chicago, Ill., Sargent and Tundle.

Biggerstaff, C. D., Kansas City, Mo., Draftsman K. C. S. Ry.

Bixby, J. E. B. Sc., E. E. '01. Denver, Colo. Telephone Dept. Western Electrical Co.

Bliss, E. F., B. Sc., E. E., '02. Schnectady, N. Y. General Elec. Co.

Bliss, C. V., B. Sc., E. E., '04. Omaha, Neb. Elec. Dept. U. P. Ry.

Bolles, C. M., B. Sc. E. E., '06. Chicago, Ill. Western Elec. Co.

Bowlby, H. L., B. Sc., C. E., '05. Seattle, Wash. Instructor in C. E. University of Washington.

- Brigham, E. W., B. Sc., E. E., '06. Schenectady, N. Y. General Elec. Co.
- Brook, I. E., B. Sc., E. E., Chicago, Ill. Arnold Elec. Power Station Co.
- Brooke, W. E., B. Sc., C. E., '92. Minneapolis, Minn. Uni. of Minn.
- Brooks, G. W., B. Sc., E. E., '02. Schenectady N. Y. General Elec. Co.
- Brown, A., B. Sc., '03. Aurora, Neb.
- Brown, G. F., B. Sc., '04. Schenectady, N. Y. General Elec. Co.
- Brockway, P. S., B. Sc., C. E. '05. Topeka, Kas. C. R. I. & P. R. R.
- Brockett, E. E., B. Sc., E. E., '01.
- Bruce, J. A., B. Sc., '03. Eng. Dept. U. P. Ry.
- Buckley, N. E., B. Sc., '03. Curtis, Neb., Roadmaster C. B. & Q. R. R.
- Buckstaff, F. B., B. Sc., '03. Chicago, Ill., Estimator, Henry Pratt
Boiler and Machine Co.
- Burkey, C. R., B. Sc., C. E., '06. Lincoln, Neb. Eng. Dept. C. B. & Q. Ry.
- Burr, F. D., B. Sc., E. E., '02. Hawserlake, Mont.
- Campbell, S. C., B. Sc., M. E., '02. Rockhill, S. C., Manufacturer of
Artificial Ice.
- Carter, A. E., B. Sc., C. E., '04. C. E., '04. Columbia University,
N. Y. City, East River Tunnel.
- Charles, E. D., Wisner, Neb. City Electrician.
- Chase, L. W., B. Sc., M. E., '04. Lincoln, Neb., Asst. Prof. Farm
Mechanics, State Agricultural School.
- Chessington, J. B., '04. Thermopolis, Wyo., Engineer.
- Christensen, W., '00. Utah, Mercur Mining Co.
- Clinton, S. D., B. Sc., C. E., '02. Eng. Dept. Tidewater R. R.
- Cole, C. L., B. Sc., M. E., '06. Milwaukee, Allis-Chalmers Co.
- Collet, A. J., B. Sc., M. E., '00. Omaha, Neb., Chief Electrician En-
gineer, U. P. Ry.
- Cornell, C. B., B. Sc., E. E., '04.
- Cortelyou, S. V., B. Sc., C. E., '02. San Fernando, Pamp. P. I. District
Engineer Fourth District.
- Costelloe, M. F. P., B. Sc., C. E., '06. Mena, Ark., Eng. Dept. K. C. S. R.
- Corr, Ray, B. Sc., M. E., '04. Indianapolis, Ind., Atlas Engine Works.
- Crane, C. O., B. Sc., E. E., Chicago, Ill., Arnold Elec. Power Station Co.
- Crook, Z. E., B. Sc., E. E., '97. Faribault, Minn., Resident Engineer
C. M. & St. P. R. R.
- Cushman, C. R., B. Sc., E. E., '02. Lincoln, Neb., Cushman Motor Co.
- Cutshall, L. A., B. Sc., E. E., '05. El Paso, Texas, Southern Inde-
pendent Telephone Co.
- Davis, C. L., B. Sc., E. E., '06. Pittsburg, Pa., Westinghouse Mfg. Co.
- Davis, E. O., B. Sc., C. E. '05.
- Davis, T. B., B. Sc., M. E. '06. Columbus, Ohio.
- Davidson, J. B., B. Sc., M. E., '04. Ames, Iowa, Professor of Agricul-
tural Engineering at Iowa State College.
- Day, W. F., B. Sc., C. E., '06. Scottsbluff, Neb., Tristate Land Co.
- Dobson, Frank, Lincoln, Neb., Contractor.
- Dormann, F. B., B. Sc., M. E., '01. Denver, Colo., American Bridge Co.
- Donbrava, H. W., B. Sc., E. E., '97. New York City, Wagner Elec. Co.

- Doubt, R. A., B. Sc., E. E., '01. New York City, Western Elec. Co.
Dumont, R. E., B. Sc., C. E., '06. Omaha, Neb., C. & N. W. Ry.
Eagleson, E. G., B. Sc., C. E., '89. Boise, Idaho, Suveyor General.
Eccles, W. R., B. Sc., C. E., '06. Mena, Ark., Eng. Dept. K. C. S. Ry.
Edwards, H. R., B. Sc., C. E., '04. Los Angeles, Cal.
Elson, W. D., Cleveland, Ohio, Western Elec. Co.
Elson, T. H., '03. Kearney, Neb.
Engel, C. W., B. Sc., C. E., '03. Omaha, Neb., C. & N. W. R. R.
Evans, H. S., E. E., '98. Boulder, Col., Prof. E. E. in University of Colorado.
Everett, C. C., Eureka, Utah, Supt. W. S. Mining Co.
Fairman, F. F., B. Sc., E. E., '06. Chicago, Ill., Western Elec. Co.
Farnsworth, G. E., B. Sc., C. E., '04. Hooper, Wash., Draftsman, North Coast Ry.
Ferguson, O. J., B. Sc., E. E., '03. Schenectady, N. Y., Prof E. E. Union College.
Forbes, B. E., A. B., '95. Fort Laramie, Wyo., Engineer U. S. Reclamation Service.
Friedman, S., B. Sc., C. E., '06. Omaha, Neb., Koenig and Collins.
Fritts, C. B., B. Sc., E. E., '96. Kansas City, Mo., Metropolitan Street Ry. Co.
Garringer, A. B., B. Sc., E. E., '00. New York City, N. Y. Telephone Co.
Geer, H. B., B. Sc., E. E., '05. Los Angeles, Cal., Los Angeles R. R. Co.
Gibbs, J. B., B. Sc., E. E., '05. Asheville, N. C.
Grant, Wm., B. Sc., C. E., '97. Lincoln, Neb., City Engineer.
Green, J. A., '04. Scottsbluff, Neb., Chief Eng. Tristate Land Co.
Green, Wm., '98. Kansas City, Mo., K. C. Telephone Co.
Griggs, C. E., E. E., '97. Utah, Mining Engineer.
Gutleben, D. B., '00. Cleveland, O., American Sugar Mach. Co.
Hagenow, Chas, B. Sc., E. E., '00. Houghton, Mech. Mathematics Instructor, Michigan School of Mines.
Hagensick, E. H., B. Sc., E. E., '06. Omaha, Neb., Elec. Dept. U. P. Ry.
Hall, D. C., '98. New York City, Electrician Navy Yard.
Hamilton, W. G., B. Sc., E. E., '06. Pittsburg, Pa., Westinghouse Mfg. Company.
Harvey, A. L., B. Sc., E. E., '06. Pittsburg, Pa., Westinghouse Mfg. Co.
Harris, R. S., B. Sc., C. E., '04. Omaha, Neb., Pres. Western Contractors' Supply Co.
Hartzell, Walter, B. Sc., E. E., '05. Pittsburg, Pa., Westinghouse Mfg. Co.
Hawksworth, D. W., B. Sc., E. E., '97. Detroit, Mich., Manager American Car and Foundry Co.
Houghton, E. H., B. Sc., E. E., '95. Chicago, Ill., Western Elec. Co.
Heaton, R. H., B. Sc. M. E., Beloit, Wis., Fairbanks Morse Gas Engine Works.
Hedge, Verne, A. B., B. Sc., C. E., '03. Lincoln, Neb., Manager Porter Hedge Abstract Co.

- Helmrod, A. A., B. Sc., C. E., '06. Lincoln, Neb., Eng. Dept. C. B. & O. R. R.
- Henck, C. H., 311 Laurel St., Baton Rouge, La.
- Henry, J. E., B. Sc., C. E., St. Joseph, Mo., Builder and Contractor.
- Hershey, J. L., B. Sc., C. E., '06. Lincoln, Neb., Beardslee Eng. and Construction Co.
- Hess, F. E., B. Sc., C. E., '03. Dallas, Texas, Bridge Engineer with Wl S. Hasey.
- Hibner, A. E., B. Sc., E. E., '06. Phila, Pa., Westinghouse Mfg. Co.
- Hitchman, J. C., B. Sc., E. E., '98. Tampico, Mex., Mexican Central Ry.
- Holmes, J. C., B. Sc., C. E., Kansas City, Mo., Waddell & Hedrick.
- Hoagland, A. L., B. Sc.; E. E., '00. Lincoln, Neb., Resident Engineer C. B. & O. R. R.
- Holman, W. H., B. Sc., E. E., '04.
- Holmes, J. C., B. Sc., C. E., '05. Omaha, Neb.
- Howe, E. D., B. Sc., C. E., '87. Table Rock, Neb., Farmer.
- Hull, A. M., B. Sc., E. E., '03. Fremont, Neb.
- Hulett, R. E., B. Sc., E. E., '99. Chicago, Ill., Western Elec. Co.
- Hubbard, R. D., B. Sc., C. E., '99. U. S. Reclamation Service
- Hummel, C. M., B. Sc., C. E., '00. Bellevilla, Ill., Chief Engineer Southern Coal and Mining Co.
- Huntington, L. M., B. Sc., C. E., '02. Panama Eng. Dept., Panama Canal.
- Hurlburt, H. S. G., B. Sc., E. E., '05. Pittsburg, Pa., Westinghouse Elec. Co.
- Hurtz, L. E., B. Sc., E. E., '03. Lincoln, Neb., General Manager Lincoln Telephone Co.
- Hunt, F. L., B. Sc., E. E., '02. Boston, Mass., General Elec. Co.
- Hyde, M. A., B. Sc., E. E., '98. Lincoln, Neb.
- Jeffrey, E. O., B. Sc., E. E., '00. Los Angeles, Cal.
- Johnson, C. A., B. Sc., E. E., '06. Pittsburg, Pa., Westinghouse Mfg. Company.
- Jones, J. C., '96. Salt Lake City, Utah, Westinghouse Mfg. Co.
- Jorgensen, H. W., B. Sc., C. E., '97. Arizona Mining Co.
- Jay, G. A., '01. Chicago, Ill., Supt. Kellog Switchboard and Supply Co.
- Kallasch, Wm., Illinois Central Ry. Bridge Dept.
- Kendall, H. C., B. Sc., E. E., '02. Milwaukee, Wis., Allis-Chalmers Co.
- Kemmish, N. A., B. Sc., M. E., '04. Lincoln, Neb., Lincoln Traction Co.
- Koch, A. W. F., B. Sc., C. E., '04. Lincoln, Neb., Eng. Dept. C. B. & Q. R. R.
- Korsmeyer, L. B. Sc., C. E., '00. Lincoln, Neb., Korsmeyer Plumbing Company.
- Krasny, Emil, B. Sc., E. E., '03. Humboldt, Neb.
- Kruse, A. N., B. Sc., E. E., '03. New York City, Western Elec. Co.
- Kuhns, J. H., '96. Prof. of C. E. in University of Japan.
- Kutton, W. G., '98. Chicago, Ill., Chicago Telephone. Co.
- Langer, J. F., B. Sc., E. E., '00. New York City, Electrical Inspector New York Navy Yard.

- Larson, C. H., B. Sc., C. E., '02.
Lawler, J. C., '02. Colorado Springs, Colo.
Leibman, M. N., B. Sc., E. E., '00. New York City, Manager Foote-Pierson Co.
Lewis, O. E., B. C. E., '84. Falls City, Neb.
Lord, H. S., B. A., '93. Butte, Montana, Civil Engineer.
Lyon, G. J. B. Sc., '99. Colorado Springs, Col., Prof. C. E. in Colorado College.
Maghee, W. M., B. Sc., E. E., '92. Rawlins, Wyo., Electrician.
Manley, F. A., B. C. E., '89. Rock Springs, Wyo., Chief Engineer Union Pacific Coal Co.
Mansfield, R. J., B. Sc., M. E., '04. Wisner, Neb.
McReynolds, R. H., B. Sc., E. E., '04. Vermillion, S. D., Supt. of Bldgs. Uni. of So. Dak.
McDowell, C. C., B. Sc., E. E., '05. Schenectady, N. Y., General Elec. Co.
McCroskey, J. W., B. Sc., '91. London Eng. Manager of J. G. White Co., Contractors.
McGeachin, W. R., B. Sc., E. E., '03. Manila, P. I., Supt. of Manila Elec. Light Plant.
Meade, A. E., B. Sc., C. E., '05. Lincoln, Neb., C. B. & Q. R. R. Eng. Dept.
Meyer, F. L., B. Sc., E. E., '97. Trenton, N. J., Roebling Sons Co.
Meller, A. A., B. Sc., E. E., '98. Seattle Wash., Sales Engineer Westinghouse Mfg. Co.
Miller, A. E., B. S. c., M. E., '06. Ames, Iowa, Instructor in Farm Mechanics, Iowa State College.
Miller, J. W., B. Sc., C. E., '05. Deadwood, S. D., Eng. Dept. C. & N. W. R. R.
Mills, D., B. Sc., E. E., '05. Omaha, Neb., U. P. Ry.
Morse, Pa., B. Sc., E. E., '93. St. Louis, Mo., Western Elec. Co.
Mueller, R. S., B. Sc., E. E., '98. Chicago, Ill., Kellog Switchboard and Supply Co.
Mundorf, Wm., B. Sc., C. E., '02. Omaha, Neb., Paxton and Vierling Works.
Newton, B. A., B. Sc., C. E., '04. Lincoln, Neb., Eng. Dept. C. B. & Q. R. R.
Noyes, H. B., B. Sc., E. E., '98. Omaha, Neb., Chief Eng. Omaha and Council Bluffs Ry. Co.
Noyes, R. E., B. Sc., E. E., '04. Schenectady, N. Y., General Elec. Co.
Oliver, R. H. B. Sc., E. E., '03. Chicago, Ill., Arnold Elec. Power Sta. Co.
Orton, C. S., B. Sc., M. E., '02. Milwaukee, Wis., Erecting Engineer, Allis-Chalmers C.
Palmer, W. R., B. Sc., E. E., '06. Schenectady, N. Y., General Elec. Co.
Pearson, C. A., '01. Omaha, Neb., Instructor Drawing, High School.
Pepperburg, A. J., '02. New York City, Navy Yard.
Podlesack, H. J., B. Sc., '94. Chicago, Ill. Electrician.

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CHARLES RUSS RICHARDS
DEAN OF ENGINEERING

To
CHARLES RUSS RICHARDS,
DEAN OF ENGINEERING,

IN APPRECIATION OF SEVENTEEN YEARS' EFFICIENT SERVICE
IN THE ENGINEERING DEPARTMENT OF THE
UNIVERSITY OF NEBRASKA, THIS
BOOK IS DEDICATED.

The Nebraska Blue Print

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THE MANUFACTURE OF ICE.

BY S. C. CAMPBELL, '62.

In mechanical refrigeration where ammonia is employed as the refrigerant two systems are used. They are called the absorption and the compression systems. The absorption system was one of the earliest methods used and the first machine was brought out about fifty years ago. The first machines were very crude, very expensive to operate and could only be operated intermittently. Some improvements were made, machines were built to operate continuously, but were very unsuccessful. The coils of pipes were subject to excessive corrosion, and were difficult to repair. A dry gas could not be obtained and such plants were no end of trouble to engineers. The trade became prejudiced against the machine and but few were built. Just within a few recent years the absorption machine has been greatly improved and on the market today can be found a machine of this type of the highest efficiency and at the same time simple in operation.

In rating refrigerating machines of all kinds, the standard unit used is based upon the cooling effect produced by the melting of one ton of ice in twenty-four hours. The latent heat of fusion of ice is 142 B. T. U., and to convert one pound of water at 32 degrees into ice at 32 degrees, 142 B. T. U. must be abstracted. Consequently we have $142 \times 2000 = 284000$ B. T. U., which is termed one ton refrigerating capacity and is the standard unit.

In the manufacture of ice from water at 80 degrees more heat must be removed or $80 - 32 + 142 = 190$ heat units per pound before the water is completely frozen. After freezing, the temperature of the ice is reduced to that of the brine, which is usually about 12 degrees. The specific heat of ice being about one-half that of water we have 10 B. T. U. more to be abstracted or a total of 200 B. T. U. per pound of water. The refrigerating machine must therefore remove $200 \times 2000 = 400,000$ B. T. U. to produce one ton of ice. Theoretically therefore we must abstract an amount equal to about one and one-half tons of re-

frigerating effect. However, considerably more heat has to be removed due to radiation, exposure, and meltage in removing ice from the cans and in practice it is assumed that one ton of ice-making is equal to two tons of refrigeration.

The working of the absorption machine is based upon the great affinity of water for ammonia gas. At a temperature of 60 degrees one part of water will absorb about 700 parts of ammonia gas. The refrigerating agent used is a solution of 30 per cent of anhydrous ammonia to 70 per cent of distilled water and is commercially called aqua ammonina. This liquid is transported in large iron drums from which it is pumped into the generator or ammonia boiler as it is sometimes called, until the system is fully charged. Steam is applied to the coils in the generator and the ammonia gas is driven off at a pressure of from 120 to 200 pounds depending upon the temperature of the water used for condensing purposes. This ammonia gas is called anhydrous ammonia and after condensation is a colorless liquid having a specific gravity of .623. In this liquid state it is ready for use in the expansion coils. The flow into these coils is regulated by a specially constructed expansion valve. The pressure in the coils being from 5 to 15 pounds gage the anhydrous ammonia quickly evaporates. The latent heat, required for this evaporation being taken from the surrounding material, produces intense cold. The boiling point of ammonia at 15.67 pounds gage is zero. The ammonia gas after evaporation passes rapidly thru the coils into the absorber forming a rich liquid which is pumped to the generator. The weak liquid in the generator is conducted thru an exchanger where it imparts heat to the rich liquid on its way to the generator, and, after passing thru a cooler, flows to the absorber. This flow is regulated by some automatic device and completes the cycle of the liquid.

The following is a description of the absorption machine built by the Henry Vogt Machine Co. The Ammonia Generator is built up of two or more horizontal cylinders bolted to a main casting on top of which is mounted another cylinder. The horizontal cylinders contain the evaporating coils of extra heavy pipe. These pipes are screwed into a heater at one end and at the outer end are expanded into a casting which also serves as a head for the cylinder. An outer casing provides the steam connection which can readily be removed for inspecting the tubes and detecting leaks. This construction makes the matter of re-

pairing the coil comparatively easy. The amount of evaporating surface depends upon the steam pressure carried in the coils.

The vertical cylinder is called the analyzer and contains a series of large and small perforated pans over which the rich liquor falls on its way to the evaporating cylinders. The entire generator is built of cast iron and is tested at a pressure of 300 pounds.

The rectifier is a cylinder containing a coil of straight tubes thru which the comparatively cool rich liquid passes on its way to the generator. The gas on its way to the condensers passes around these tubes. The function of the rectifier is to cool the gas and condense any watery vapors that may be held in suspension, thus delivering a dry gas to the condensers. The rectifier is placed adjacent to the generator and is provided with a drain to the same.

The condensers for ammonia gas may be submerged, atmospheric or double pipe. The first type, as the name indicates, consists of coils entirely submerged in a tank of water. The cooling water enters at the bottom of the tank and overflows at the top while the ammonia gas enters at the top and the ammonia liquid is led from the bottom to the receiver.

The atmospheric condenser is built in a zigzag pattern of continuous pipe connected by a vertical header at each end or by using straight pipes with return bends making a vertical coil. The cooling water trickles over the pipes and considerable heat is carried away by the atmosphere. Where water containing salt or scale forming material is used the coils soon become coated with scale and are subject to excessive corrosion at the ends where the supply of water may not at all times cover them.

The double pipe condenser is built of two concentric pipes. The water flows thru the inner pipe and the gas passes thru the annular space. Access is easily had to the water pipes and one condenser may be cut out, cleaned and repaired without disturbing the ammonia connections. The water pipes are fixed at one end and pass thru stuffing boxes at the other to allow for expansion. The double pipe type is the most economical in the use of water and is the most convenient to use as it may be placed within the building. However, condensers should always be placed where there is a good circulation of air. The size of condenser depends entirely upon the temperature of the water supply.

In applying refrigeration either the direct expansion system or the brine system may be used. In the direct expansion system the liquid ammonia is piped to the rooms to be cooled and there expanded in coils, directly taking up the heat. In the brine system a transfer medium consisting of some solution, having a low freezing point, is used. This solution is first cooled to the desired temperature and then circulated thru the rooms. In the manufacture of can ice, it is necessary to use a transfer medium and a tank must be provided for this solution. This tank is built of one-quarter inch steel and is made of sufficient size to accommodate the required number of cans for a given capacity.

The cans are made of galvanized iron No. 16 sides and No. 14 bottoms with an iron band at the top. The regular 300-pound can is 11"×22"×44". Eight cans are allowed per ton and the freezing process is completed in from forty-eight to fifty-four hours.

The expansion coils are placed in the tank so that they will be as close as possible to the sides of the cans which are placed as close endwise as the frame work of the cover of the tank will allow. Each coil is made of one continuous welded length of 1¼ inch extra heavy pipe. One expansion valve is used which regulates the flow of ammonia. The ammonia gas enters at the top of the coils, passes thru them and from the lower manifold to the absorber.

The absorber is of the vertical type. The shell is made of heavy boiler plate and the tubes of extra heavy charcoal iron tubing. The water enters at the bottom passes up thru the tubes and overflows at the top. The ammonia gas from the expansion coils enters at the top and is distributed thru the absorber by a perforated pipe which extends almost to the bottom. The weak liquid from the generator enters at the top and the pump suction is near the bottom.

The ammonia pump is of the fly wheel type and designed to run from twenty-four to thirty revolutions per minute. This pump takes the liquid from the absorber at the lower pressure and forces it into the generator at the higher pressure. The ammonia cylinder is directly behind the steam cylinder and an intervening water chamber which surrounds the ammonia stuffing box acts as a lubricator and prevents leakage.

The rich liquid on its way from the pump to the generator passes thru the rectifier, explained above, and also thru an ex-

changer which is similar in construction to a double pipe condenser. The rich liquid enters the inside pipe at the bottom of the coil and coming from the top passes directly to the analyzer of the generator. The weak liquid from the generator enters the annular space at the top of the exchanger, passes thru the coil, imparting heat to the rich liquid, into a weak liquid cooler which is identical in construction with the double pipe ammonia condensers and thence thru the regulating valve into the absorber.

In the operation of the machine the best results are obtained with the lowest steam pressure possible on the generator, the richest liquor possible, and the lowest pressure possible in the absorber. The last is necessary where low temperatures are carried. By referring to tables of properties of saturated ammonia we find the boiling point at 15.67 pounds gage to be zero, at 9.1 pounds, —10 degrees and at 6.29 pounds, —15 degrees with the latent heats 555.5, 561.16 and 564.6 respectively. The lower temperature enables a much more rapid transfer of heat.

The ammonia passing to the coils must be pure and dry as the boiling point is affected to a great extent by impurities and the efficiency lowered. One per cent of water entrained in ammonia will lower the economy of the machine 3 or 4 per cent. Hence the necessity for having an efficient rectifier or dehydrator. After the machine is charged with aqua ammonia of the required strength it is seldom necessary to replenish the charge unless lost by accident. However, it is impossible to prevent the loss of ammonia gas thru the stuffing boxes of valves and other leaks which will develop by intermittent operation. A sample of rich aqua ammonia can be drawn from the system and tested with a hydrometer. This should show not less than 26 degrees Baume at a temperature of 60 degrees F. To strengthen the charge anhydrous ammonia may be expanded into the system. This ammonia is transported in cylinders containing fifty or one hundred pounds. The ammonia should be tested before using as manufacturers guarantee purity and a cylinder contaminated with foul gases will give no end of trouble. It may be tested for dryness by drawing a sample from the cylinder into a test tube, quickly inserting a stopper with a small outlet and being careful that no moisture collects inside of the tube. The ammonia will evaporate rather slowly unless immersed in brine. Any residue will be the moisture contained. Foul gases may be

detected at the instant of complete evaporation by leaving an offensive odor. They will not be absorbed by water and are readily detected by a rise in the absorber pressure.

The absorber is provided with a purging valve above the level of the liquid where these gases accumulate and may be burned off. They will burn with a yellowish flame which is extinguished by the presence of ammonia. Ammonia gas will not burn.

All valves and fittings used for ammonia are made extra heavy and are of cast iron or steel as other metals are rapidly corroded. A leak of ammonia in the brine tank is very destructive to the galvanized cans.

A constant supply of water is necessary for the operation of the machine and the pumping plant is of greatest importance. The machine will require about four gallons per ton per minute. The absorber requires an ample supply of cold water if a low temperature in the refrigerating coils is desired. With cooling water at 60 degrees, 70 degrees and 80 degrees back pressures of 2, 4 and 8 pounds respectively are obtained. However, less water may be used and the machine operated successfully at a higher back pressure. The amount of heat generated in the absorber depends upon the amount of ammonia in circulation as the heat of absorption is about 925 B. T. U. per pound of ammonia. This amount of heat must be again applied in the generator as it is supposed that the heat of dissociation is equal to the heat of absorption, altho both vary somewhat with the strength of solution. Very little data is available in regard to the economy of plants of various sizes. Tests that have been made compare favorably with the compression machine and theoretical calculations show a decided advantage in the absorption machine. It has been found that the machine will use about 30 pounds of steam in the generator per ton of ice. In refrigeration the machine most economical in the use of steam is the one desired. In the manufacture of distilled water ice where the operation of the machine will not furnish sufficient water for ice making the economy lies in the distilling system which we will next consider.

In the manufacture of can ice which is frozen in 50, 100, 200, 300 or 400 pound blocks it is impossible to obtain the desired purity for domestic purposes without distillation and seldom without reboiling. In the manufacture of plate ice which

is frozen from one side only filtered water may be used. Freezing will neither kill disease germs nor eliminate suspended matter. However, the freezing process will drive suspended matter ahead of it and clear ice may be harvested from filthy ponds. The plate system operates on the same principle. The water to be frozen is run into a vat or tank about thirty inches wide and several feet long. The water freezes around the vat and when about two-thirds frozen the ice is removed leaving practically all the impurities in the unfrozen water. These blocks weigh several tons and are sawed into sizes convenient to handle. In the can system all the water in the can is frozen and therefore must be entirely free from air and suspended matter to produce transparent ice. Water may be free from suspended matter, but the presence of air will produce a white core in the ice, which has a disagreeable taste and odor. Ice may have a red, white or yellow core all of which are due to defects in the distilling system and oftentimes it is difficult to locate the defect. In the absorption system the condensed steam from the generator and live steam from the boiler form the greater part of the water used and little or no difficulty will be experienced from the use of oil. In the compression system practically all the steam is contaminated with lubricating oil which proves to be a great source of trouble. However, a skimming tank is used in connection with the reboiler, but the skimming process wastes a certain amount of water.

The boiler must be blown off at regular intervals and kept clean. The water level must not be carried too high or priming will occur and spoil the ice. However, manufacturers guard against this to a certain extent and specify a boiler about twice the size necessary thus reducing the rate of ebullition. The water from the steam condenser passes into the reboiler, which is a galvanized tank containing a coil thru which live steam is passed in sufficient quantity to boil the distilled water more or less violently. Machines are in operation without reboilers and produce a fairly good quality of ice. However, it depends largely upon the character of the water which must leave the condenser at a temperature near the boiling point or foul gases will be reabsorbed. The best way to remove the air and foul gases is by a violent reboiling, altho there is a considerable loss from the escaping vapor. The reboiler is fitted with a float and regulating valve to keep the coil covered and the discharge

pipe full of water. It is a matter of the greatest importance to have all distilled water pipes galvanized, absolutely air tight and so arranged as to remain full of water at all times. The water leaves the reboiler at a temperature of about 212 degrees and passes into a forecooler in order to lower the temperature as much as possible before entering the cans. The forecooler is a large vertical cylinder fitted with coils for cooling water and also coils thru which the ammonia gas passes from the refrigerating coils on its way to the absorber. The gas enters the coils at about 12 degrees and by using plenty of cooling water the temperature of the distilled water may be reduced as low as 36 degrees. The forecooler also acts as a storage tank from which the water is drawn as needed, passing thru some type of filter on its way to the cans. The filtering medium used should be such that all suspended matter will be removed. Charcoal, fine sand, quartz, sponges, and cloth are used successfully. Charcoal, having the property of absorbing gases, is most extensively used. However, its value in that respect is rather limited and would require frequent renewals. Charcoal filters are sometimes used two or three seasons without renewing, but will not remove small particles of rust and other suspended matter. The most effective filter in removing all particles of rust is one using special cloth and fibre discs. The cloths may be washed and the fibre discs discarded as they can be replaced at a small cost.

Red ice is invariably due to rust in the system and is most likely to occur after a shut down. White ice is caused by air and foul gases in the distilled water. The reboiler may not be working properly or the gases have been absorbed after leaving it. Yellow ice is a result of oil in the system. However, there are other causes which may produce one result at one time and at another time a different result. This subject could be discussed at some length and is of the utmost importance to the ice manufacturer.

The brine in the freezing tank is a solution of either common salt or calcium chloride. The latter having several advantages, altho much higher in price, is slowly replacing salt. There are several grades of calcium on the market and the cheaper products are more destructive to the tank and pipes than salt. A pure calcium undoubtedly has many advantages over salt. It is non-corrosive, and will clean the tank and pipes from

rust and scale. For that reason it is not always advisable to change from salt to calcium, as serious leaks may develop in the tank. The brine should be of sufficient strength to remain liquid at the lowest temperature carried. Ice plants of recent construction are built to carry a temperature of about 12 degrees in the tank and freeze a 300 pound block of ice in from forty-eight to fifty-four hours. However, many plants are in operation carrying a temperature of 18 degrees and freezing in seventy-two hours. Brine tanks are often built of wood and a few have been built of concrete. They should be insulated with some good insulating material as granulated cork or mineral wool with several thicknesses of boards and insulating paper. Wooden tanks are usually built of six inch lumber and require very little insulation. It is a matter of some difficulty to make them absolutely tight when calcium is used. The tank should be provided with some agitating device as a rapid circulation of the brine is conducive to quick freezing. Either a direct acting steam pump with suction and discharge at opposite ends of the tank or a rotating agitator placed at one end of the tank may be used.

In the operation of an ice plant the best results are obtained by continuous operation. Ice must be pulled regularly and cans filled at regular intervals. All machinery should be kept in first-class order. Special attention should be given to the boiler plant and more care exercised than in an ordinary steam plant. The economy lies in the generation of steam as other expenses about the plant are fixed. A can plant will produce from five to eight tons of ice per ton of coal. Some plants produce as low as three and others as high as ten depending somewhat upon the quality of coal used. A plate plant will produce from ten to fourteen tons of ice per ton of coal. However, the initial cost of the plant is much greater.

The cost of production will vary from 75 cents to \$2 per ton, depending upon the size of the plant and the price of fuel. Retailing this ice to the large consumer at \$4 or \$5 per ton and to the small consumer at from \$7 to \$10 per ton gives the inexperienced the impression of enormous profits in the ice business. Taking into consideration the fact that the plant can be operated at full capacity possibly four months out of the year while some skilled labor must be retained the entire year, the cost per ton of ice manufactured would reach a surprisingly high figure.

Adding to this the cost of delivery, including the large item of shrinkage, the cost of maintaining such equipment and wintering the same the per cent of profit is materially reduced and brought within reasonable limits.

The cost of installation depends largely upon the location, the ease with which water may be obtained, the kind of a building and the storage capacity. Equipment for a can plant aside from the building will cost from \$650 to \$800 per ton installed ready for operation. Building and water supply from \$300 to \$400 per ton. In a plate plant the equipment is more expensive and will cost about \$1,000 per ton with the same expense for buildings as in a can plant.

TEST WORK AT CHICAGO'S THIRTY-NINTH STREET PUMPING STATION.

BY E. H. BROWN AND C. L. COLE, '06. ALLIS-CHALMERS CO.

THE PUMPING STATION.

The complete turning of the sewage of Chicago from Lake Michigan, into the river and drainage canal, occasioned the building of an extensive intercepting sewage system and several large plants. The sewage through the plants reaches its destination by a series of steps. At 73d street and near the lake is a small station into which the sewage from the south and southwest flows. Here it is discharged into one large conduit 12.5 feet in diameter, at an elevation high enough to flow to one farther north. This conduit, following the lake front 4.5 miles, enlarges as it crosses the intercepting sewers to 16 feet in diameter at 39th street station. Again the sewage is elevated by specially designed sewage pumps, until by gravity it flows directly west through a conduit 20 feet in diameter, into the stock-yards slip, and from the slip into the south branch of the Chicago river, finally entering the drainage canal.

Fig. 1.—The 39th Street Pumping Station.

The largest of the sewage pumping stations is located on the edge of the lake at 39th street, just outside of the tracks of the Illinois Central Railroad. Figure 1 shows this plant looking at it from the south. Its function is threefold in that it cares for the dry weather sewage, the flood water or storm sewage and sends a large volume of lake water into the river and drainage

Fig. 2 — The Centrifugal Unit.

canal. Four centrifugal and two screw pumps were installed to perform these respective duties.

The rated capacity of the pumping station is 1,296,000,000 gallons per 24 hours, but by a little crowding the units will deliver 2,000,000,000 gallons, thus making its capacity the largest of any in the world. The larger capacity was shown to be possible on one of the tests, for by decreasing the head pumped against and increasing the speed a few revolutions per minute

the pump discharged 140 cubic feet per second against its rated capacity of 75.

The maximum dry weather sewage that flows into the 39th street plant is near 150 cubic feet per second and to handle this, two centrifugal pumps of 75 cubic feet per second capacity, are installed. The pumps are driven by triple-expansion engines 12 by 22 by 32 and 30 inch stroke. They operate against a head of 20 to 24 feet and with a speed of 110 to 120 revolutions per minute. The sewage and storm water that may flow into the suction well is 666 cubic feet per second and two pumps of 250 cubic feet per second capacity care for the additional flow. The storm pumps have cylinders 16 by 30 by 46 and 30 inch stroke,

Fig. 3—The Centrifugal Engines as Arranged Across the South End of Building

operating against a head varying from 7 to 10 feet and with a speed of sixty to ninety revolutions per minute. Figure 2 shows the engine and pump, and figure 3 the arrangement of the four units at the south end of the engine room. The engines are well lagged and equipped with reheating coils in the receivers. The unique feature of the sewage and stormwater units comes in the arrangement of the cylinders. They are placed 120° apart, as shown in figure 2; thus dispensing with a fly-wheel, and the connecting rods drive over a single pin. A fan shaped counter-balance on the end of the vertical shaft relieves the difference in the reciprocating parts.

For improving the sanitary conditions and relieving the velocity in the Chicago river, two screw pumps, driven by marine vertical engines of the fore and aft type, were installed. These pumps have a capacity of 666 cubic feet per second and operate against a head of 7 to 10 feet. Their function is to pump lake water. The engines are triple-expansion, steam jacketed, reheating coils in receivers, having cylinders 22 by 38 by 62 and a 42-inch stroke, the speed being fifty-five revolutions per minute. Figure 4 shows the screw pump pit and condensers. Figure 5 shows the arrangement of the cylinders, the high and intermediate being in tandem and the low pressure cylinder to the side. The condensers of the barometric type Allis-Chalmers Co. design

Fig. 4 —The Screw Pumps.

are equipped with 8 inch centrifugal circulating pumps, direct connected to American Blower Co. engines and produce a working vacuum of 27 inches.

The centrifugal and screw pump units were designed and built by the Allis-Chalmers Co. of Milwaukee, Wisconsin.

The six pumping units are contained in a spacious engine room 125 by 135 feet, with head room for the barometric condensers, over which runs a fifteen-ton crane of 100 feet span. Centrifugal and screw pump units were designed and built by the Allis-Chalmers Co. of Milwaukee, Wisconsin.

The plant faces the lake with the longest way to the north. The main interceptor coming from the south, makes a turn at

the south-west corner of the plant and extends across the entire south end of building, making another 90° turn it enters the gravity channel as shown in figure 6. The chamber at the south

Fig. 5.—The Cylinders of the screw Pump Unit

s the suction well for the sewage and storm pumps. The sewage s taken from this channel and discharged into the gravity hannel which runs parallel, but west into the main cross-town onduit. An automatic swing gate hangs across the suction

Fig. 6.—The Plan and Arrangement of Channels and Engines.

channel and the storm pumps may be used either for pumping lake water or storm sewage. If for storm sewage, the lift gate to the gravity channel is closed and when the sewage rises to 8 or 10 feet below datum, the automatic gate swings open and this part of the interceptor becomes the suction well for the storm pumps. The bottom of the suction well is 34 feet below floor level and the discharge or gravity channel is 32 feet. The channels in width are 12 and 11 feet respectively.

The intake for lake-water, also shown in figure 6, is horse-shoe in shape and has a capacity of 120,000 cubic feet per minute. By this arrangement each screw pump has a separate suction channel, the intake dividing into three channels at the entrance to the building, the lake water being cut off by steel, motor operated, lift gates. The three channels passing under the building, and converging at its west wall, form the 20-foot cross-town conduit previously mentioned.

The boiler room, 48 by 50 feet, extending across the north end of the building, contains six water-tube boilers in batteries of two units. They are of the Babcock Wilcox type and were built by the Aultman-Taylor Co. The boilers are equipped with chain grates and special coal handling devices, and are rated at 264 horse power each. They are capable of furnishing steam for the entire plant should it be found necessary or desirable to run at full capacity. Steam lines 6 inches in diameter lead from the boilers to a header on brackets along the south wall. At the west a 6-inch main leads from the header, through the wall and half way around the engine room, furnishing steam for the smaller centrifugals. At the east end of the header, a 10-inch main leads to the screw pumps, and from there on a 7-inch main, supplying the storm pump, continues around to meet the 6 inch in the middle of the engine room, thus making a complete circuit. The three sets of units can be separated by gate valves.

The coal handling machinery is of the Jeffrey's manufacture. A grab bucket and electric hoist takes the coal from the cars and drops it into a coal bunker and receiving room. A hopper, electrically driven on a runway, takes the coal from the bunker and distributes it to each of the boilers.

THE TESTING APPARATUS.

The three factors beside time which determined the duty of the pumping units, were the weight of commercially dry steam used by the engine, the capacity of the pump or the weight of

water or sewage pumped, and head pumped against or the height to which the water was lifted; and in measuring the quantity of each of these, an independent apparatus was employed.

For the steam consumption, standard methods were followed as closely as possible, but for the other two no such standards were available.

With the type of condenser used it seemed impracticable to weigh the exhaust steam from the engine, so the boiler feed water was measured and deductions made for all trap and separator discharges between the boiler and the throttle and for boiler leakage.

Fig. 7 - The Boiler Feed Tanks

FEED WATER.

The feed water measuring apparatus consisted of two elevated weighing tanks, A and B, figure 7, resting on scales and arranged to discharge into the lower receiving tank C, which was connected directly to the feed pump. The weighing tanks, of galvanized iron and stiffened by hoops, were 4.5 feet in diameter by 3 feet deep and were provided with 3-inch quick opening gate valves, connected to the bulging bottom so as to

completely drain the water. With each tank was a measuring stick graduated to read pounds directly, when held vertically in the water, giving the weight in the tank at any time. The tanks were supported by a substantial timber frame resting on the scale platform. The scales were Fairbanks manufacture and tested and found correct with standard weights by the city examiner of weights and measures.

The receiving tank below is 5 feet in diameter, 4 feet deep, with a 2-inch connection to the pump let in at the side near the bottom and contains a heating coil for warming the feed. In this tank is a galvanized iron float carrying a pointer which moves over a scale reading in pounds.

The feed water is pumped directly to the boiler used during the test thru a special line of pipe, the other connections being blanked. This boiler was blanked from the header and its steam carried directly to the engine-room main thru temporary piping. The engine room steam main, as previously mentioned, runs completely around the building and is connected to the boilers, thru the header at both ends.

During the test of any unit all connections, except to the test boiler, were blanked and all drips, separator and trap discharges were conveyed thru special piping to a cooling coil and then to a weighing tank in the engine room; the steam passing from the separator, thru the engine into the barometric condenser and the condensed steam and circulating water running from the hot well to waste.

The percentage of moisture in the steam was determined by means of a throttling calorimeter, drawing steam from the pipe between the separator and throttle valve, thru a sampling nipple with its end plugged and the side toward the current of steam drilled full of small holes and reaching to the middle of the steam pipe.

The steam pressure was taken at the calorimeter by a Crosby test gage and the temperature in the instrument indicated by a calibrated thermometer. The steam pressure at the boiler and all receiver and reheating coil pressures were taken from standard Bourdon gages, tested for accuracy by a Crosby gage tester. The vacuum was read from a mercury column connected to the exhaust pipe and the atmospheric pressure from a Keuffel and Esser Aneroid Barometer.

The revolutions of the engine were recorded on an Ashcroft

Engine Register, driven from the high pressure exhaust wrist plate.

HEAD.

For the two sewage pumps, the amount of sewage flowing was not the specified capacity of the pumps and in consequence one of the storm pumps had to take care of the surplus, discharging it thru the south screw pump channel and thence into the cross-town conduit outside the building. This arrangement limited the level of the water in the suction well to a point somewhat above the lower sill of the automatic swing gate opening into the storm pump suction chamber and consequently necessitated the raising of the discharge water level several feet above that obtaining when sewage only is pumped. This was accomplished by placing timber bulkheads, of 10 by 10-inch hard pine, in the cast iron slots let into the wall on each side of the discharge nozzle as shown in figure 8, and pumping into this reservoir. The bulkhead nearest the lake was built up to the floor, but the next one in place was provided with an orifice, the area of which could be adjusted by a steel plate suspended from the floor, and this bulkhead was only built to the height which gave the desired total head on the pump with a part of the water flowing over its top and part thru the orifice. As the sewage flowing and therefore the suction level was subject to changes due to rains and other causes, this flexibility of apparatus for controlling the total lift was essential.

The total head pumped against was defined as the difference in level of the water in the suction and discharge channels, shown in figure 9, and it was this distance which had to be measured.

The city datum of Chicago was taken as a base line and the distances of water levels above or below it, designated positive or negative respectively and measured by means of floats carrying pointers and reading on scales graduated in tenths and hundredths of a foot.

On the discharge side, the float was placed between the two bulkheads, A and B, figure 8, and as the water surface in this section of the channel was always within a few feet of the engine room floor, the pointer was carried on an extension attached directly to the float. The float was made of galvanized iron, square in section and with a pyramid top. Into the apex of the pyramid, was let a quarter inch pipe coupling and this served to

15

14

13

Fig. 8.—Gravity Channels, Showing Bulkheads and Control of Flow of Sewage.



Fig. 9.--Section Three Centrifugal, Showing Total Head on Pump

hold the extension of quarter inch pipe, to which the pointer or indicating finger was attached. A water-tight wooden box, 12 by 12 and 1-inch boards, fastened securely to the concrete wall of the channel and with a contracted opening in the bottom to the water outside, guided the float and prevented any wave action from affecting it. Directly above this box on the engine room floor, a vertical board was fastened to carry the scale, graduated in feet above city datum and over which the pointer traveled, the extension of quarter inch pipe being guided by bands on the board.

The calibration of this apparatus was simple, accurate and direct. The elevation of the engine room floor was $+11.0$ feet with respect to city datum and as the water level was usually $+9$ to $+10$, the pointer of the float was clamped to the extension, a sufficient distance above the water line, to bring it on the level of the eye of an observer standing on the floor. This arrangement made necessary the setting of the pointer a known distance above the water line of the float and the raising of the zero of the scale over which it traveled, the same distance.

To place the pointer, the float with extension and pointer attached, was placed in a box of clear water and guided so as to float in a vertical position and the water line marked on its side by a fine line; the pointer then being placed any desired distance above the water level by simply measuring with a steel tape from the line on the float to the pointer.

For setting the scale a surveyor's level was used and a reference line of known elevation placed on the supporting board by leveling from the building's bench mark. If the water surface was to be shown directly on the scale, the scale reading corresponding to the reference line elevation would simply be placed at this line, as the pointer was to indicate the water level, its distance above the surface was deducted from the reference line elevation and the number thus obtained marked on the scale and placed opposite the reference line. This operation being simply equivalent to raising the scale zero enough to make the pointer indicate zero with the water surface at datum.

The elevation of the floor at the gage was determined accurately and its corresponding readings checked by direct measurements from the floor to the water surface.

The level of the water in the suction well was, during the sewage pump tests, from 13 to 15 feet below datum and as it

was necessary to take the observations from the floor, the distance from the water surface to the line of observation was about $38\frac{1}{2}$ feet to $40\frac{1}{2}$ feet and made the arrangement somewhat more complicated. A float and guiding box of about the same construction as was used on the discharge side were employed, but it was not practicable to attach a pointer to an extension, because of the great length, the fluctuation of the water level at various times and the limited head room.

The guide box was bolted to the concrete wall of the suction well, directly under a manhole in the floor and over the center of the box a vertical gage board was placed and a line drawn across it at about the level of the eye.

Then an extension was attached to the float whose top just came to this mark when the water stood at datum or zero and to the top of the extension was clamped a steel tape which ran over a pulley at the top of the gage board and was weighted at its free end. Evidently the number on the tape opposite the observation line will indicate the distance the water surface is below datum. However, it was not feasible to locate the line of observation by raising the water surface to datum and as this position would be from 13 to 15 feet above the level prevailing during the tests and might involve cumulative and other errors, the following calibration was devised. Near the bottom of the box was placed the opening to sewage, this being a pipe with a valve to adjust the opened area and to close it altogether. Several feet above this another pipe was tapped in the box horizontally with an ell on the end and a short nipple looking up from the ell. The elevation below datum of the end of this nipple was accurately determined by means of a surveyor's level. The extension having been placed on the float and the tape attached and all adjusted roughly to bring the observation line or zero marks about 5 feet above the floor level, everything was ready to determine the position of the zero mark accurately. The lower opening to the box was closed by the valve and the box filled with water till it spurted out the vertical nipple, the float rising with the water; then the lower valve was opened and the water allowed to fall till it stood just level with the top of the nipple. The elevation of the end of nipple being known, that of the water surface when it stood at this point was also known and therefore the zero mark on the gage board would be opposite the reading on the tape corresponding to this elevation. The

zero mark was thus determined and checked repeatedly by observers stationed at the nipple and signaling to the others above at the gage board who would instantly mark opposite the tape reading for the nipple elevation.

This gage showing the suction level in feet below city datum and the discharge gage the water level above datum, gave the head pumped against by simply adding the two observed distances.

CAPACITY.

To determine the capacity of the pumps current meters were employed to measure the velocity of flow at a section of known area and this method entailed considerable apparatus and experiment to produce satisfactory and accurate results.

As shown in figure 8, the water on leaving the pumps entered the reservoir formed between the two timber bulkheads, A and B. It was discharged from this reservoir, partly thru an orifice in and partly over the top of B, into the gravity channel and flowed west over a submerged bulkhead C with a floor 10 feet long fastened to its top, into the cross-town conduit. At D, outside the engine room, a sectional steel bulkhead was placed and arranged to adjust vertically and thus give any desired depth of water at C, where the current meters were suspended and the velocity observations taken.

The distance between B and C was limited and as at C, the meter station, the flow to be straight and of uniform variation from top to bottom and side to side, it was necessary to discharge the water from the reservoir with a minimum of disturbance. This was accomplished by means of the orifice in B, the area of which was adjusted from the floor above by raising or lowering a steel plate over part of it. The orifice area was set to give a flow of from 4 to 6 inches depth over the crest of the timbers and this falling sheet served to break up eddy currents and boiling due to the velocity of discharge below.

To still the water and break up cross currents, giving it a parallel flow free from swirls, three stilling racks made of 2 by 10 inch by 16 feet pine boards, spaced 10 inches to center, were weighted and suspended between B and C, a fourth rack being built on the edge of the floor at the meter station. Floats made of 2 by 12 inch boards were used to quiet the water surface.

Directly over C, the current meters were suspended from steel cables and lowered into the water at this point. As it was neces-

sary to take observations of the velocity at practically all points of the measuring section, three meters were employed and arranged to be moved laterally and vertically. They were suspended from steel cables wound on wooden drums for raising and lowering; these drums also carrying weights on steel cables wound in the opposite direction, to balance the weight of meter and attached weight which was provided to keep the current from forcing the meter from a vertical position.

Each drum was provided with an operating handle and was of such a diameter that one revolution raised or lowered the meter two feet.

To provide for lateral motion the drums were mounted on four-wheeled carriages which ran on an elevated track over the opening in the floor. A pointer on the carriage passing over a scale on the track indicated the meter position with respect to the channel-wall, and the end of the drum was marked off in spaces equivalent to a vertical motion of 0.1 of a foot.

Three Price horizontal wheel current meters were used, each being calibrated at the government station at Chevy Chase, Maryland. Figure 10 shows the meter apparatus and the meters attached ready for lowering to the current. The current meter revolutions were indicated by electrical buzzers, the circuit being opened and closed once every revolution by a spring coming in contact with a cam on the shaft of the meter bucket wheel.

TESTS.

The duty of each unit under contract conditions was determined by a twenty-four-hour continuous test, in the presence of the city's representatives, Allis-Chalmers engineers, and a third or disinterested party, chosen by the city and Allis-Chalmers Company.

The logs of the tests were kept by experienced observers on forms supplied, two carbon copies being made.

Prior to the official twenty-four-hour tests, the builders conducted a series of preliminary tests in which the defects in the machines were detected and remedied, all apparatus tested and operated and the most economical conditions as to head, speed, capacity, etc., within the limits allowed by contract were determined. Just before each official test a preliminary duty test of from six to twelve hours was run under the conditions set for the official test, also in the presence of the city's representatives.

Fig. 10.--Current Meters and Carriages

The manipulation and working of all apparatus during the tests was made as simple and free from error as possible.

The feed-water weighing tanks, being of such construction as to completely drain and give a constant tare, allowed the scales to be set at a fixed gross weight and it was only necessary for the operator to balance the beam, and enter on the log the number of tanks used. At the signal for the beginning of the test, the number of pounds in the lower receiving feed tank were observed on the graduated scale provided and entered on the log together with the level of the water in the boiler, which was shown by a scale set behind the gage glass. To obtain the feed water for an hour the water in the receiving tank was brought back to the amount the log indicated at the start, and the weight of water in the tank then emptying taken by a graduated stick held vertically in the tank. As each tank emptied was 1,200 pounds, the feed water pumped was equal to the number of tanks at 1,200 pounds per tank, plus the fraction of a tank observed. If the water level in the boiler had varied, a correction was applied to the feed water pumped, to get the net feed water used. The correction was obtained by calibrating the boiler, 0.10 inch on the gage glass being equivalent to a definite number of pounds, depending on the pressure observed.

In the engine room the water of condensation in the pipes was taken from the traps and weighed at intervals of one-half hour, the gross, tare and net weights being entered in the log, together with the time of weighing.

The amount of steam discharged thru the calorimeter was calculated by Napier's formula for the flow of steam thru an orifice; viz., weight in pounds per second is equal to the absolute pressure multiplied by the area of orifice in square inches divided by 70. The diameter of the orifice was carefully calipered and the accuracy of the formula checked by a preliminary test, in which the steam discharged per hour was condensed and weighed.

The leakage of pipes and boilers was obtained by running a leakage test directly after the duty trial for a period of several hours and during which all conditions were kept as nearly as possible to those prevailing in the duty test. The amount of leakage was taken as the weight of feed water necessary to keep the water in the gage glass at the same height.

The net saturated steam used by the engine was obtained by

deducting the trap discharge, the steam used by the calorimeter as calculated and the boiler leakage, from the feed water pumped, corrected for any difference in boiler water level at beginning and end. The net dry saturated steam being this quantity times the quality. The steam was assumed dry unless the moisture exceeded 2%, and in all instances but one the moisture was less than 2%.

The condenser circulating pump was an 8 inch centrifugal, direct connectd to a 6 by 6 inch, American Blower Co. high speed vertical engine and as the main engine was charged with the steam to operate this auxiliary apparatus, the exhaust of the circulating engine was sent into the first receiver and worked thru the intermediate and low pressure cylinders.

Two indicators were attached to each cylinder and to the circulating engine and cards taken on all simultaneously, once an hour, the load being practically constant. Crosby Indicators were used, the drum being driven from a pantograph reducing motion, and the springs calibrated by the makers.

All temperatures, pressures, and revolutions were observed every fifteen minutes thruout the test.

The water controlling devices were so arranged that the most uniform steady flow was usually obtained with a mean velocity at the measuring section over bulkhead C, figure 8, of about 1.7 feet per second and this velocity was produced by altering the depth of water over C with the steel bulkhead D, to give the required discharge area. The depth of water on the platform at C was indicated by a float gage reading to hundredths of a foot, and set in a slot in the wall directly over the bulkhead and opposite the meter positions.

As before stated the velocity of the water was measured by Price, large sized, electric current meters suspended in the water at this section. The meters were attached to the pivot rods below the lead weights provided to hold them against the current, so as to obtain observations within a few tenths of a foot from the bottom and within half a foot from each side.

Each revolution of a meter was indicated by the electric buzzer and observers with accurate stop watches, reading to tenths of seconds, counted the revolutions. This method of counting was taken in preference to electric registers due to their liability to jump or miss.

In observing the velocity over the discharge area the point

method was used, that is, each meter was placed in one position, the number of revolutions in a period as near as possible to 60 seconds counted and the period in time in seconds and the number of revolutions entered on a log together with the position of the meter with respect to the channel walls and bottom.

The measuring section was divided into 96 areas or points and each of the three meters held at 32 of these in succession, while the revolutions were being counted. The points were placed, 8 vertically, 0.55 feet apart and 12 horizontally, 0.92 feet apart, the channel being about 11 feet wide as shown in figure 11, which is a section X-Y, over the platform built on C, figure 8, the average depth on the platform being 4.4 feet.

The carriages of the three meters employed were rigidly

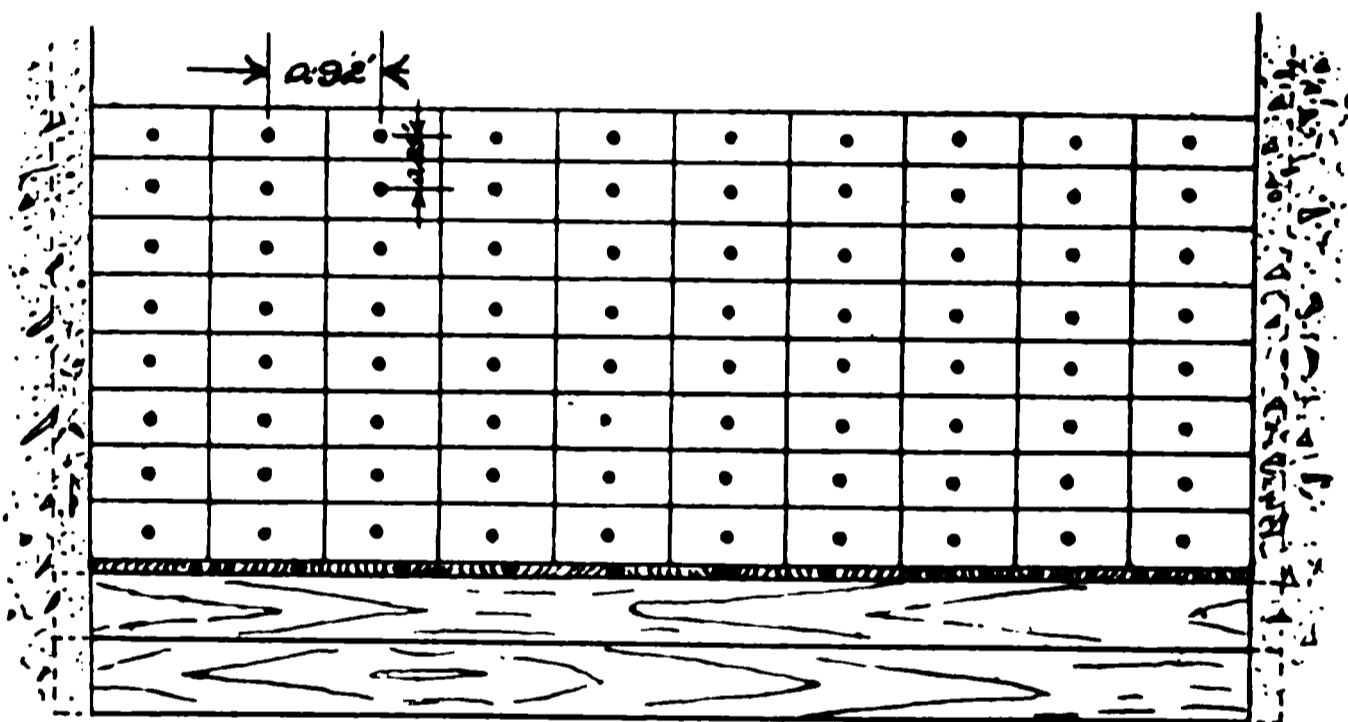


Fig. 11.—Showing Position of Meter at Measuring Section.

fastened together and of such a distance apart as to allow each meter to take four sets of eight vertical readings.

In operation the meters were placed at the required distance from the channel walls, lowered to the bottom position and eight observations in a vertical line, taken when an operator would move them laterally to the next position and the performance repeated until the 96 points were covered. About one hour was required to pass over the section once, which gave time for the placing of the meters to the observation points and for frequent examination of the instruments to see that strings and other matter, carried thru the pumps in the sewage, were not lodged on the bucket wheel spindle of the meter.

During the test the time and revolution columns on the log sheets were simply totaled and averaged and the average velocity

in the channel taken as the velocity corresponding to the revolutions per second thus obtained and the hourly capacity computed from this.

For the final computation, however, a somewhat more elaborate and accurate method was devised. On the log sheets the revolutions per second were obtained for each observation, slide rules being used in this work, and the corresponding velocity in feet per second read from the calibration curve for that particular meter. The calibration curve for each meter was obtained by plotting the revolutions per second as abscissae and the velocity in feet per second as ordinates from the rating sheet for the instrument. With a complete reading for each hour this gave 24 observed velocities for each of the 96 points and the average velocity at each point was taken as the average of the twenty-four.

From side to side the points were arranged in twelve vertical sets of eight each; so with ordinates representing depth of water or meter positions above bottom in feet and abscissae as velocity in feet per second, twelve vertical velocity curves were plotted. The area under each curve was obtained by the use of a polar planimeter and the mean velocity for each of the twelve vertical sections found by dividing the area by the depth of water. The twelve mean velocities were then plotted as abscissae with the width of channel as ordinates and a curve drawn as figure 12, showing the lateral variation in mean vertical velocities. This mean curve was integrated and the mean velocity in the channel found.

For check work, the eight horizontal sets of twelve velocities each were plotted and the mean velocities from the resulting curves obtained and laid off with the depth of water for ordinates. A curve was then drawn through the points, showing the vertical variation in the mean horizontal velocities and the velocity obtained from it averaged with the mean of the vertical curves, this being taken as the channel velocity for computing capacity.

The width of the channel at the measuring section was carefully measured with a steel tape and calipers and the depth of water observed at each velocity observation or thirty-two times an hour. The channel width in feet multiplied by the average depth of water gave the area and this times the mean velocity gave the capacity in cubic feet per second.

The density of sewage pumped was tested by a hydrometer

and by weighing a known volume and was usually slightly heavier than pure water.

The indicated horse power was obtained from the cards in the usual manner.

The suction and discharge heads were observed every fifteen minutes thruout the test.

The duty was obtained by transforming the capacity from

Depth Water on Platform - Ft

Velocity - Ft. Sec

512

Width of channel - Ft

Velocity - Ft Sec

Fig 13.

Fig 12 Mean of Velocities in Horizontal Planes. Fig. 13.—Mean of Velocities in Vertical Planes.

cubic feet per second to cubic feet per twenty-four hours, multiplying by the weight per cubic foot of sewage, and the total he pumped against and dividing by the thousands of pounds commercially dry steam used by the engine.

On the two sewage pumps, the guaranteed duty was 95,000 000 foot pounds of work done per 1,000 pounds commercial

dry steam and the two storm pumps 85,000,000 with a bonus of \$1,000 for each 1,000,000 foot pounds in excess of the guarantee. Approximately \$20,000 bonus has been earned on each of the three units tested.

The preparations for the tests presented some interesting problems and difficulties, especially on the water end, which could not be dwelt on in this general article and which were overcome only after a great deal of experiment and hard work.

In conclusion, it would be well to call attention to the fact that most of the foregoing descriptive matter of the tests applies most directly to the 75 cubic feet per second sewage pumps, some slight alterations being made in the apparatus for the 250 cubic feet per second storm pumps.

RECORDS.

BY E. E. HOWARD, WITH WADDELL & HEDRICK, CONSULTING BRIDGE
ENGINEER, KANSAS CITY, MO.

The making of records is one of the most interesting habits of civilized man. This habit has contributed more than any other one of his activities to the development of intellectual power, knowledge and science. The applications of science to the processes of human industry, which constitute engineering, depend for their accuracy and efficiency very largely upon the kind of records that experimenters and research workers keep of their discoveries. And to still further narrow this universal field, in which record-making plays such an important part, the making and keeping of records of strictly engineering enterprises is fundamentally necessary to the conduct of the work with that precision, economy, and ultimate usefulness which should mark the efforts of a man trained to do a thing in the best way. The young engineer who apprehends the importance which accurate and well-kept records play in the conduct of all engineering business, and who early fits himself to do his own part well, in what record-making has to be done by himself, as a beginner as well as in more responsible positions, will increase his usefulness as an engineer and perhaps avoid some of those sins of omission which rise up to block every man's course of advancement.

An able railway engineer and manager recently said, "In the modern management of railway and manufacturing plants, efficient results are obtained by the ability to tell definitely the relative efficiency of men, methods, machinery and appliances, by some unit of measure. On a steam railroad the unit of measure is what it costs per ton per mile to handle freight." He further observed, that at the inception of a great undertaking, "The first object is to train men to keep those costs, and to keep them accurately."

As engineering has to do with all branches of science and business, there are records to make of many different kinds. When an engineer prepares a design, as a banker he has records of money; as a merchant records of prices; as a bookkeeper

records of costs ; as a railroader records of tariffs ; as a producer records of materials ; as a manufacturer records of manufactures ; as a lawyer records of law ; as an artist records of eternal fitness ; as a historian records of achievement ; and as a poet records of his own imagination.

Engineering is not wild guessing ; it is materialized, systematized, scientific imagining. In addition to being able to imagine what may be done, an engineer must have the records of what has been done ; for only so can such imagining be scientifically economical. It would be a sad thing if each inventor had to go back to the beginning and repeat all the work of his predecessors.

My desire is to outline something of the records an engineer may be interested in, from perhaps a slightly different point of view than the reader has heretofore had. Many of the articles written on records consist of a bewildering number of examples of "forms used," leaving little coherent impression of the principles of record keeping. So many, so universal are to be records to be made by the engineer, so constantly does he make them, and so wide are the ramifications that the work assumes, that I can but direct attention to a general view of the subject, with a few illustrations. If you determine in your own mind the necessity and importance of this part of your work, your own ingenuity will develop the details.

Take for example a single structure from its inception to its completion. Assume it is a bridge. Somebody calls on the engineer to find out about building the structure, and the records begin. Letters are the first record. Then comes examination of the site, and investigation of bridges in a similar position. The preliminary report, a preliminary estimate of some sort, more letters, record of decision to build, surveys and borings with records, designs with records, specifications, drawings (records themselves), records of contracts, records of construction, records of field-work, monthly estimates, records of acceptance, final record of completed structure,—and you have left your engineer little time but to make records.

It is not necessary for the young engineer to wait until he is called on to do some large work, before he begins to make records in line with his chosen profession, for he cannot proceed at all without this record-making being thrust upon him.

Records are made for information, to preserve and convey

thought. It is axiomatic to say that the record should be clear and plain. Records are for others as well as ourselves. If the thought is worth recording at all, it should be done in such fashion that it will convey information of a definite, intelligible sort. Here are two primary principles in record-making:

Records are for information.

Paper is cheap.

Legibility is of first importance, and should be attained, even though it is sometimes troublesome and expensive to do so. A commonplace subject which deserves attention is good hand-writing. Writing is good if it is legible, whatever the style of penmanship, and no amount of ornate capitalization will atone for subject matter that cannot be easily read. Legible and orderly writing and figuring will advance the beginner in the estimation of everyone with whom he has business. The time when a young engineer will have his own stenographer to take care of the legibility of his correspondence and records may be far distant; it is worthy of careful consideration that almost the first immediate connection the beginner will have with engineering will be making his part of certain records, and in that part, hand-writing and figuring will be the main factors. By "write" I do not mean literary composition, but merely the mechanical act of "tracing or inscribing symbols or ideographs."

Assuming then a serviceable, legible system of characters, here is another important principle of record-making.

SYSTEMATIC ARRANGEMENT.

An orderly allotment, a systematic arrangement of symbols, of characters, of words, terms, and of every detail of a record, is essential to make that record complete. Accuracy is enhanced by a symmetrical, methodical apportionment and classification of data; while a record, however complete, if put together in a chaotic, ill-arranged way, may lead to confusion,—and the purpose of records is information, easy, accurate information.

The next important principle of record-making is permanence. Of all deplorable, unsystematic habits of record-making, none is so bad as the making of desultory notes on loose sheets. Records should be kept in books, or bound into books, or some workable substitute. In some of the large drafting rooms of the structural shops of this country, every mark of a pencil is required to be put down in a scratch-book; each and every simple

arithmetical operation, all so they can be found when the inevitable checking up comes. Too often it happens, if notes are made on such nondescript sheets, that they are misplaced or lost even before they are old; and one is forced to the undignified and annoying attitude of looking in the waste-basket. Such a necessity in an engineering work is an indication of a lamentable lack of system; for engineering information should be recorded so as to be available. To quote from two well-known passages in literature, "Order is Heaven's first law," and "What thou seest write in a book."

I have had to take a dozen small pieces of paper, torn off a little scratch-pad neither numbered nor marked by headings, and by successive alternative arrangements find from them the notes to determine sizes and elevations for the abutments of a bridge. It would be superhuman if such practices did not lead to errors and subsequent expense, for straightening out preventable errors.

As well as forcing some systematic arrangement, an additional advantage books have is that they are a step, at least, toward permanency. The necessity for permanency in many records that have to do with the expenditure of money, your own or some other man's, is so well recognized by good business men that every engineer should feel his own obligation to keep his own records in permanent shape.

All are familiar to some extent with the usual field-books for engineer's records, and with forms for certain notes.

It is customary and in accord with every idea of order to have similar notes follow a set standard. But even these standards are oftentimes arranged and filled in in such a way that no one, even the maker, can after a lapse of time determine the meaning of the notes.

The field notes of a survey, of a pile-driving outfit, of a force-account, of anything, ought to contain all the information at hand in some sensible arrangement. For instance, a pile-recorder may proceed to systematically designate the piles in the bents as No. 1, 2, 3, 4, and 5, and that may be clear in the notes; while you may search in vain to find whether he counted from the east, west, north or south.

It not infrequently happens that the preliminary draft of notes of some kind must be made hurriedly, or under circumstances which prevent a perfectly satisfactory final record being prepared at the time. The trouble and expense of doing some

piece of preliminary work all over again may arise from losing all or a portion of a set of notes before they have been put in permanent shape. The first notes, too, should always be kept so that they can be referred to when necessary, for confirmation.

Field notes should be concise yet comprehensive. In making them, everything should be put down that the taker thinks will be needed, and then all the things he thinks he will remember. They should contain all the facts of the matter in hand, yet they should be to the point and concise. But the conciseness must not be carried to the point of leaving out information which another person would need in checking over the notes, and it is from the standpoint of the other fellow that notes should generally be taken and kept. Faulty memories show themselves at the most inconvenient times; the employees in charge of certain branches of work change; and the only safe standard is to have an intelligent record that any intelligent man can comprehend. Two words need not be used where one would serve, but that one should not be omitted.

The value of comprehensiveness in records and the way to secure it was impressed upon my mind once on an inspection trip, when examining a number of bridges. The engineer whom I accompanied made the notes, while I did the climbing around, in addition to which I made my own notes. Each time I would be through and impatient to move on to the next bridge, and he would still be writing notes. When the time came for accounting, and the notes were to be worked up, mine were decidedly lacking, and his contained information which I had instinctively left to memory, and of course a fallible memory.

Comprehensiveness without discrimination is, of course, "multiplying words without knowledge." Notes may be made so verbose as to be bunglesome, bootless labor, just as is the painstaking gathering of witless data.

A form of record adaptable to all engineering work, and to all engineers from the student to the specialist, is the working diary. Such a record almost never comes amiss; its value is so well-known, that comments are almost superfluous. The persistent regularity with which a diary must be kept going is extremely trying, yet in personal satisfaction over the absolute knowledge it gives of past events, which a diary contributes in such degree, it repays all the labor expended. In case of dispute, such a record is almost invaluable, and in legal affairs it is ac-

corded marked consideration, even if merely used to refresh memories ever growing stale. No more praiseworthy habit can be formed than the keeping of a continuous diary of facts. No one's life is so bare, but there are matters worthy of record,—facts which may become of use. A personal experience on the witness-stand, where a small diary served as an appreciated staff, is fresh in the mind of the writer, and served to impress upon him the great use of such records.

Letter writing and correspondence form one of the most universal and important forms of record. Letters betray characteristics to the distant recipient, neatness or slovenliness of body or of mind, and impress him for or against us inevitably. Moreover, the most important thing in any business transaction is for the letter to convey to the recipient the meaning intended by the writer. Use the words that will convey to someone else the impression you want to make. The composition of a letter must conform to this rule to be effective. When you get through saying something, stop.

When you send away a record of yourself into the hands of another person at a distance, you ought to have a copy of that record for your own satisfaction and safety. A most primary business caution that can always be practiced with benefit is the preservation of a copy of all letters of a business nature. The copy press is usually available, or the convenient roll-book may be used.

The proper filing and keeping track of letters has among modern business men, reached a high degree of efficiency. A method once much in vogue was to file all letters received alphabetically and consecutively, and an answer to all letters would be found in the press copy-book of the same date. This scheme has some advantages, but is now largely supplanted by filing under subject and individual, briefly outlined as follows:

To each letter a carbon copy of the reply is attached; and it is possible immediately to trace through the whole correspondence on a given subject. Each letter written deals about one matter preferably, or about allied points of one matter; and where several widely different subjects are to be attended to, a separate letter is to be written on each. Take for illustration a manufacturing concern—each piece of work will be given a contract number and a folder provided for each correspondent who writes about that contract; one general folder or drawer or

box is provided to include all the individual folders, and the whole correspondence about the contract is at once at hand. Often you see on business letters this legend, "Please refer to File No. —." And often also a line stating the subject. In addition to the carbon copy of the letter, a press-book copy is kept. You will find substantially this system in use in most of the railroad offices, as well as in private business concerns. Any system of filing or recording correspondence has the same end in view, of a systematic arrangement of the records to secure their permanence and availability. A discussion of filing is equally applicable to all other kinds of records, as well as to letters. Numerous systems have been developed and are in use for keeping records of various kinds. The best system for a given case is dependent on the particular phase of information wanted from that record, and the frequency of that want. These two factors must be approximately determined, and a filing system developed accordingly. For instance, Tuttle & Pike in Kansas City do a very large city survey business, and they have developed a system of indexing the notes of their innumerable surveys for past years, so that in an astonishingly short time they can give you the references to a lot corner or a street corner. It is the daily, maybe hourly occurrence to seek such references. In other offices of slightly different scope of work, this careful indexing of street references is not necessary or desirable; for that particular form of information is required only at intervals, and it is economical to spend more time looking for a reference than much time in the preparation of an index to be but seldom used. It is well to remember that indices and files are useful only as they lighten the total labor and expenditure of time. There is no sense in spending more time in sharpening the ax than in cutting down the tree.

This is the age of the Card Index. It confronts us on every hand; it shouts with capital letters on the street-car advertisement, and everyone knows that no matter what he has to file, no matter what kind of data he is troubled with, no matter how limited or extensive his filing needs may be, everything is provided for. A more satisfactory system has not been invented; but in becoming enthusiastic over any cataloguing scheme, it must be always remembered that the index is the servant, not the master; the means, not the end.

Drawing as a means of recording and conveying thought is

one of the most interesting to me of the methods of making records. To originate a detail or combination of details, and then to put down on the drawingboard your plan and your detail so as to carry out your scheme, is a most engrossing occupation. In plans, the same as in other records, the identical, axiomatic, obvious, simple rule holds sway. The record, if not intended merely for personal use, must convey to someone else a meaning. The humiliation of an inexperienced draftsman whose plan, on being manufactured by some mechanic, turns out different from what he intended, and with good reason, from the workman's standpoint, is not the only unfortunate result of a drawing which does not embody data so arranged as to be understandable by the user as well as the maker.

One matter which should receive care in plan-making is the mutual correlation of various parts. Usually in an extensive work, contractors or mechanics have plans only of their particular share, and build in accordance therewith, trusting entirely to the detailer that their portion will fit to the work of the other builders. Especially when a change is made on one drawing or on one detail, it should be traced throughout all the parts that may be affected. For instance, I have set anchor-bolts according to substructure plans, only to find later that the steel-work would not fit, a mistake due wholly to limited corrections.

If a drawing is made for construction, it is well to remember that, however easy it may be in the drawing-room to spread three or four sheets out on a desk and compare from one to another to find one lonesome dimension, it is an entirely different thing when you are shoe-deep in mud, with the rain dripping on your print.

A plan should either frankly acknowledge that the details are to be left to the user, or else should give every detail exactly. If the former, well and good; the user can proceed on a basis of adapting his own ideas, and the maker of the plans will become a smaller and smaller factor in the matter. Unless it shows him what it pretends to, a plan is a trouble instead of a help; unless a map really indicates the geographical relations it is supposed to, it is of little use. There is some discussion from time to time regarding shop-drawings for structural steel, as to when the advantage and economy of making them ceases and it becomes advisable to lay out in the shop directly without

templates. The same general proposition is met with in any kind of drawing. To work to that point only in accuracy of detail which will be of advantage to the ultimate end, should be the aim of the plan-maker.

In the main, the deficiencies of drawings as records, aside from the matter of ordinary mistakes and ordinary errors, are due to a lack of conception on the part of the plan-maker as to how the user of the plans will perform the work. The natural conclusion is that only the man who has done the class of work involved can properly make the plan. This is not always practicable, but it is always possible for the designer and detailer to have clearly in his mind just how he would take each step, if he were to follow the plan and build thereto. Sometimes you will come across the plan of a structure, a careful examination of which will show that it has been made so that it will be utterly impossible to construct the work by any known method. In fact it would be necessary for the whole edifice to spring into existence at once. It is not uncommon to find in steel-work instances where members must first be taken apart before they can be put together, and rivets which no human riveting tool can drive. I have seen plans, supposedly complete, for substructure for bridges and arches, from which it was not possible without considerable additional figuring, to proceed to the laying out of the work, even though the sheet was abundantly supplied with dimension lines and certain dimensions. If the maker of a plan could not lay out his work from his own drawings, he accords a superior wisdom to someone else to make anything out of them.

A carefully made plan is certain to save expense in time and labor by having the thinking out done only once. The leading features and dimensions should be given the most prominence, and the lesser followed out in regular order, till those details are reached which will be worked out in less time by the user than by the maker. Above all, in making plans intended to convey information, there must be information to start with.

An important form of record for promoting the advancement of engineering knowledge, is the record of completed work. Sometimes the anxiety to stop expense immediately on the cessation of work causes records to be left in an unfinished condition, and at later times this turns out to be an expensive economy. Theoretically, when a piece of work is finished, the records of that work are finished also, but practically this does not always

follow, and a short time spent in indexing and arranging working notes when they are fresh, will save much time later. For instance, it may at some time be of importance to know quickly just how deep the piles of a certain trestle were driven, or what load a certain floor was figured for, or what pressure per square foot was allowed on certain material, or even who inspected certain work. The idea sometimes expressed, that now we have our building, or bridge, or embankment, or cut, we can look at them and tell how big they are, is so unwise that its prevalence is surprising. When a work is completed, the best thing is either to make a new drawing showing the structure as built, or better, perhaps and cheaper, is to take the tracing of the original plan, and mark "As built" on each governing dimension, and give data of revision, in no case erasing the original plan. For it sometimes happens that after a lapse of time plans are looked up for some data as to the existing structure, and it is easy to confuse the actual with the original plan, it being rare indeed that a plan is carried out in detail as at first contemplated. Aside from the personal value of a record of completed work, there is a value to the profession at large. It is essential that records be made of complete work, so that it may be studied later as a basis for the general engineering information which we all depend on for the advancement of the profession.

The criticism may be made that the keeping of such exhaustive records is so expensive, and demands so much time and attention, that after all it is not worth the pains necessary to keep it. Records, of course, are utilitarian. Every engineer must determine for himself how far he will go, and how completely he will keep his records. The purpose of this article is to emphasize the prime importance of record-making in general, and the characteristics it must possess to be valuable as record-matter. The various branches of the science of record-taking and keeping can be determined by each engineer as he goes along, and he must decide where to draw the line between expense and completeness of record. But he should realize that the record is, in general, one of the most important features of an engineering undertaking, and that the ability of making appropriate records for a given piece of work, is something he should devote himself to acquiring.

To summarize the principles the writer considers important to keep in mind in the making of engineering records, the following points may be mentioned:

Records are for information, therefore they should be
Legible,
Concise, and
Comprehensive.

To which end there should be skillfully made symbols, orderly, systematic arrangement, and definite ideas of information desired.

They should be
Permanent,
Accurate, and
Intelligible.

It may be borne in mind that memory is fallible; paper is cheap; that books were invented to keep together loose sheets; that if a record is correct one time, it usually never needs to be made over again; the only safe rule is to make the record entirely complete when preparing it. To be usable, records should be so filed and stored as to be available; for the beginning where we start, and the ending where we finish, has the one criterion,

RECORDS ARE FOR INFORMATION,
and the test for a record is
WILL THIS INFORM?

Record-making is but one of the details of our profession, but perfecting that detail will be of advantage, on the whole, in order that past achievements may be surpassed, that the deserved confidence and status be accorded our profession, in the minds of the general public, and that more economically and more efficiently the great forces of nature may be utilized for the advantage of mankind.

THE OPEN-CIRCUIT AND SHORT-CIRCUIT CHARACTERISTICS OF THE INDUCTION MOTOR.

BY V. L. HOLLISTER, INSTRUCTOR IN ELECTRICAL ENGINEERING.

The open-circuit characteristics of the induction motor sometimes called the "excitation" curves are two in number, plotted as in figure 1. Curve A is plotted between E M F and current

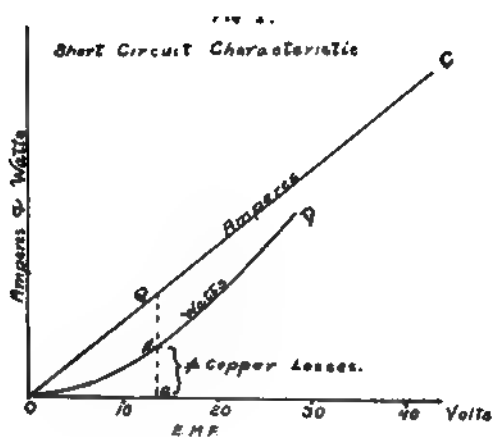


Fig. 2

with the former as abscissæ. Curve B shows the relation existing between the watts input and impressed E M F using watts as ordinates.

Figure 2 is similar to figure 1. Curves C and A corresponding, and curves D and B being plotted similarly. The curves of figure 2, however, are plotted from the readings taken on short circuit.

The data for plotting figure 1 is obtained by running the induction motor light, without load, and impressing various voltages on its primary winding from 20% above normal to a smaller value just sufficient to turn the rotor in its bearings. The least voltage possible to supply the motor with enough energy to keep the rotor revolving will probably be such a value as O P on the curve. The corresponding watt input will be represented by the ordinate P B, such energy supplying the friction and windage of the motor plus the iron and copper losses. At zero impressed voltage there would be no iron nor copper loss, and as we assume that the friction and windage remain constant, extending the watt curve to the axis of ordinates as at C gives the value (O C) of friction and windage loss. Extending C H parallel to O T we find the energy input S L at normal voltage O S and subtracting S H, the friction and windage, we obtain H L the iron and copper loss. The current intake at normal voltage is S M. The angle of lag θ of the magnetizing current S M is

$$\theta = \cos^{-1} \frac{SL}{\overline{OS} \times SM}$$

If we knew the resistance of the primary of the motor we might easily obtain the input into the rotor for any load, since we can measure the input into the primary and it is possible to compute the losses and subtract them. That is, we may subtract from the input primary the I^2R primary, neglecting the so-called load losses, and thus obtain the input into the secondary. Now, if we can obtain the losses in the secondary and subtract them from the input secondary it will be possible to figure the efficiency of the motor.

There are two losses from the secondary, the heat loss and the friction and windage.

The value of the latter has been found, but to obtain the former we must know the resistance secondary. The latter may

be obtained very easily for a wound secondary; for a squirrel cage rotor, however, direct measurement is impossible. The resistance of such a winding may be obtained, however, as explained later.

The data for plotting figure 2 is obtained by blocking the rotor of the motor, *i. e.*, clamping the revolving member of the motor so as to prevent rotation. Increasing voltages are then applied to the primary windings from approximately 5% of normal pressure to a voltage such that not more than 150% full load current will flow through the windings. The maximum pressure possible to fulfill the above condition will probably never be more than 50% of the normal value for which the motor was designed. The current which would flow at full normal voltage is obtained by direct proportion since the curve is a straight line. The watt intake may likewise be figured since the watts intake vary directly as the square of the impressed voltage.

The current intake for full voltage as is figured above is an index to the starting torque of the motor, when the power factor is taken into account. More useful to the designer, however, is the relation between the current intake at full voltage blocked rotor and the current S M for full voltage obtained from figure 1. The leakage coefficient (σ) sigma, is a quantity which good design demands to be made as small as possible. Its value is obtained by dividing the value S M by the starting current of the motor—the full voltage blocked rotor current.

It is from the short circuit characteristic that we may obtain the resistance of a squirrel cage secondary. At a voltage impressed such as O G the corresponding watt input is G.N. The current input is G Q. If we subtract the I^2R primary $= \overline{GQ}^2 \times R_p$ from the watts input G N we obtain the watts I^2R loss secondary. Dividing the latter value by the square of the primary current gives the secondary resistance reduced to primary by the square of the ratio primary turns to secondary turns or simply reduced to the primary circuit.

The value obtained above is not strictly accurate since there is a small amount of iron loss even at the very reduced voltage O G. The smaller we take O G, however, the more insignificant will the error become.

A relation which interests the designer is obtained from figure 1. The line O H' is drawn from O tangent to curve B. It

cuts the normal voltage line $S M$ at J . The line $J L$ is a measure of the iron losses in the motor, while the line $H J$ is a measure of the losses in the air gap, *i. e.*, the exciting energy necessary to overcome the reluctance of the air gap for the given density of magnetic lines.

Having obtained the above characteristics and data for a motor it is possible to compute the theoretical efficiency of the motor for any output. Suppose we wish an output of Z horse power, what input into the motor will be necessary?

The input will necessary be $Z \times 746 + I^2 R_{\text{primary}} + I^2 R_{\text{secondary}}$ plus the friction wattage $H S$. The corresponding efficiency of that output must be

$$\text{Eff.} = \frac{Z \times 746}{HP \times 746 + I^2 R_p + I^2 R_s + HS}$$

The torque of the motor is expressed by

$$T = \frac{7.04 [Z \times 746] + I^2 R_s}{\text{Synchronous speed.}}$$

The use of the above data as outlined to determine the performance of the motor is not to be encouraged except as a ready check for less careful work, or in lieu of the absence of available apparatus to make a prony brake or rated generator test. The data and characteristics obtained above would enable the designer to construct the Heyland or circle diagram for the induction motor. From the latter every detail of the performance could be obtained. I refer the interested reader to any of the standard books on alternating current motors for a complete description of the circle diagram for the induction motor.

One who is familiar with the testing of direct current machinery will appreciate the difference between such tests and the usual "stray power" tests on alternating current machinery. The latter in nearly every case consist of obtaining the data for the open circuit and short circuit characteristics. Alternators are driven from a rated motor or thru a dynamometer, and the power necessary to drive them on open circuit is found for various values of excitation. The machine is next driven under reduced field current with the armature short circuited thru an ammeter. From the latter readings the power necessary to supply the copper losses and the load loss is obtained.

For the test of a transformer the same characteristic curves are obtained from which the full performance of the transformer is obtained. Such curves are shown in figures 3 and 4.

The relation referred to above,—that where the secondary resistance may be found from the short circuit characteristic,—is nicely illustrated by calculations based on data taken from the curves shown in figure 4 (page 54).

The resistance of the primary of the transformer was measured by the fall of potential method. It is taken as 27.4 ohms. From the short circuit characteristics the following data are taken from points on the curves:

| | E. MF. | Watts | I | Calc. Sec. Res. | Measured Sec. Res. |
|---|--------|-------|-----|--------------------|-----------------------|
| 1 | 70 | 50 | .98 | .062 | .. |
| 2 | 40 | 15 | .54 | .0606 | .061 |
| 3 | 30 | 9 | .42 | .06 | .... |

For point No. 1 the secondary resistance is calculated as

$$\frac{50}{.98^2} = 52.2$$

$$52.2 - 27.4 = 24.8$$

24.8 = secondary resistance reduced to the primary by the square of the ratio of primary to secondary turns. The transformer used for this test had a ratio of 20:1, therefore

$$\frac{24.8}{20^2} = .062$$

Similarly for point No. 2 the secondary resistance is obtained as

$$\left[\frac{15}{542} - 27.4 \right] \frac{1}{20^2} = .0606$$

and for point No. 3

$$\left[\frac{9}{.42^2} - 27.4 \right] \frac{1}{20^2} = .06 -$$

These figures are tabulated in column No. 5 and are to be compared with the value of the resistance for the secondary of this transformer found by direct measurement.

This example shows the accuracy that may be expected from the above method when applied to the induction motor with the squirrel cage rotor.

The efficiency of the above transformer is readily calculated for any load. The core loss is obtained by noting the watts input at normal voltage with open circuited secondary and subtracting from the same the copper loss for the current input at that voltage. When the core loss has thus been determined, the primary resistance measured, and the resistance secondary measured or calculated as above, the efficiency may be calculated from the formulæ.

$$\text{Eff.} = \frac{\text{Input} - \text{core loss} - \text{copper losses}}{\text{Input}}$$

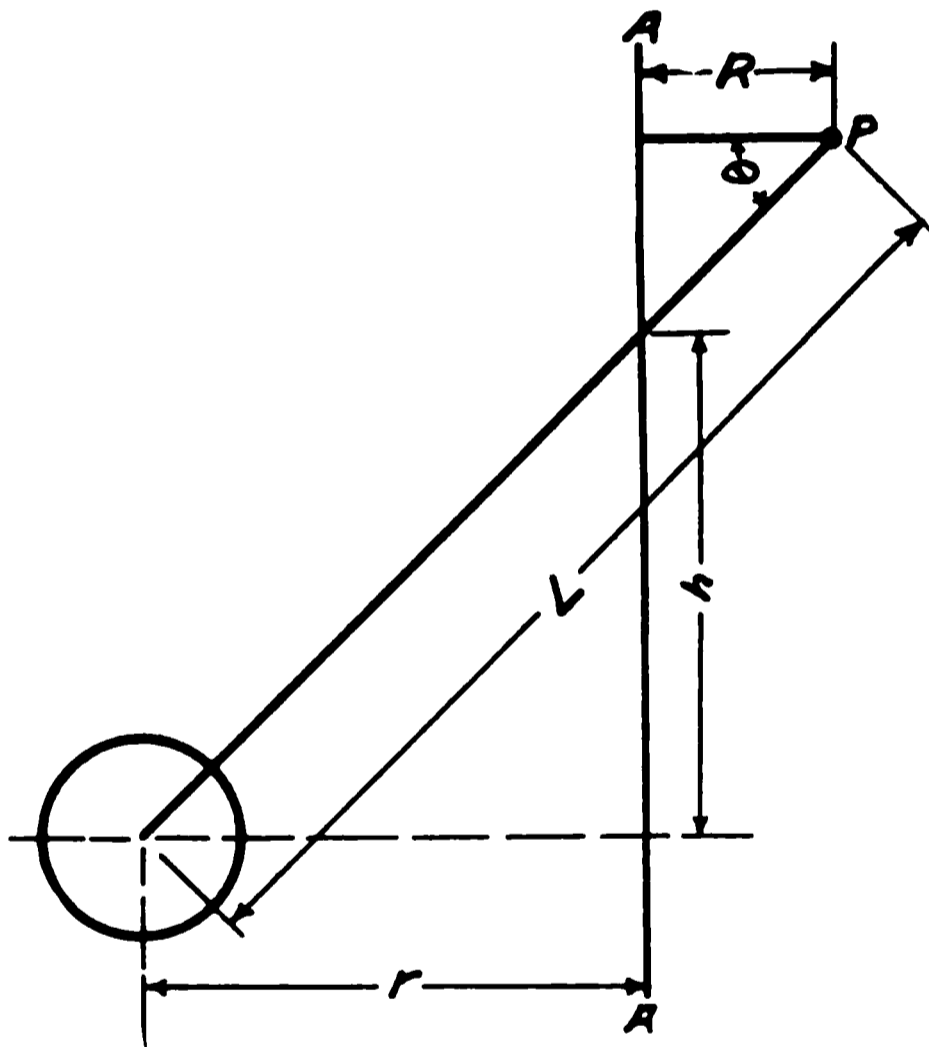
At 110 volts on the above curve the core loss is found to be 59 watts less $1.9^2 \times .06 = 58.64$ watts core loss. Call it 58 watts. The Westinghouse transformer No. 313658, capacity 2 K. W., as tested above showed a full load efficiency, neglecting full load magnetizing current of —94.8%. It is calculated as follows:

$$\text{Eff.} = \frac{2000 - 58 - 19^2 \times .06 + .95^2 \times 27.4}{2000} = 94.8$$

THE CROSSED ARM FLYBALL GOVERNOR.

BY G. L. HEDGES, '07..

The theory of the crossed arm type of flyball governor may be considered the general theory for flyball governors. The advantage of this type over the ordinary type with the point of support of the arms in the axis of revolution is that it may be designed so as to be more nearly isochronous and therefore will govern more closely. The effect of a central load on this type of governor is the same as with the ordinary type, namely, a small change of speed produces a larger movement of the balls with a high speed of rotation, and the governor is more powerful.



Let the figure represent the diagrammatic skeleton of a crossed arm flyball governor of the pendulum type.

P = Point of support of the arm of the pendulum.

AA = Axis of revolution.

R = Distance of the point of support P, of the arm of the pendulum from the axis of revolution.

L = Length of the pendulum arm.

h = Height of the cone of revolution.

r = Radius of rotation of the flyballs.

For any given governor R and L are constants. For any constant speed of rotation the ball revolves at a corresponding

distance r from the axis of revolution, the centrifugal force F , pulling it out being balanced by the weight of the ball W acting downward.

Taking moments about O

$$F \times h = W \times r \text{ or } F = \frac{Wr}{h} \quad (1)$$

$$\text{also } F = \frac{4\pi^2 n^2 r W}{g} \quad (2)$$

$$\text{therefore } \frac{Wr}{h} = \frac{4\pi^2 n^2 r W}{g} \quad (3)$$

from which $h = \frac{g}{4\pi^2 n^2}$ where h = height of the cone of revolution

n = revolutions per second.

It will be evident from an examination of the figure that h equals 0 for two values of θ namely, $\theta = 0$ and $\theta = \cos^{-1} \frac{R}{L}$. There must therefore be a value of $\theta = \theta_c$ where h would have a maximum value, between these values of θ .

$$\text{From the figure } h = L \sin \theta - R \tan \theta \quad (4)$$

$$\frac{dh}{d\theta} = L \cos \theta - R \sec^2 \theta \quad (5)$$

For h to be a maximum put $\frac{dh}{d\theta} = 0$.

$$\text{then } L \cos \theta = R \sec^2 \theta \quad (6)$$

$$\cos \theta_c = \frac{R^{\frac{1}{3}}}{L^{\frac{1}{3}}} \text{ and } \theta_c = \cos^{-1} \frac{R^{\frac{1}{3}}}{L^{\frac{1}{3}}} \quad (7)$$

$$\sin \theta_c = \frac{\sqrt{L^{\frac{2}{3}} - R^{\frac{2}{3}}}}{L^{\frac{1}{3}}} \text{ and } \tan \theta_c = \frac{\sqrt{L^{\frac{2}{3}} - R^{\frac{2}{3}}}}{R^{\frac{1}{3}}}$$

substituting these values in (4) we get

$$\text{maximum } h = L \left[\frac{\sqrt{L^{\frac{2}{3}} - R^{\frac{2}{3}}}}{L^{\frac{1}{3}}} \right] - R \left[\frac{\sqrt{L^{\frac{2}{3}} - R^{\frac{2}{3}}}}{R^{\frac{1}{3}}} \right] = \frac{[L^{\frac{2}{3}} - R^{\frac{2}{3}}]^{\frac{3}{2}}}{[L^{\frac{2}{3}} - R^{\frac{2}{3}}]^{\frac{1}{2}}}$$

As n varies as $\frac{1}{h}$ this value of h determines the lowest speed at which the governor will operate.

The table gives the values of N_c and θ_c for several different combinations of L and R. It sometimes requires considerable "cut and try" figuring to find the best combination for any particular case.

| L = | 6" | | 8" | | 10" | | 12" | | 15" | | 18" | |
|------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| R | N _c | θ _c | N _c | θ _c | N _c | θ _c | N _c | θ _c | N _c | θ _c | N _c | θ _c |
| 0" | 77 | 90° 00' | 66 | 90° 00' | 59 | 90° 00' | 53 | 90° 00' | 48 | 90° 00' | 44 | 90° 00' |
| 1/4" | 83 | 69 50 | 71 | 72 00 | 62 | 73 00 | 57 | 74 00 | 50 | 75 00 | 45 | 76 00 |
| 1/2" | 90 | 64 00 | 76 | 66 30 | 66 | 68 10 | 60 | 69 30 | 53 | 71 00 | 47 | 72 00 |
| 1" | 100 | 56 30 | 82 | 60 00 | 71 | 62 20 | 63 | 64 00 | 55 | 66 00 | 50 | 67 00 |
| 2" | 121 | 47 30 | 95 | 51 00 | 79 | 54 00 | 70 | 57 00 | 60 | 59 00 | 53 | 61 00 |
| 3" | 161 | 38 00 | 118 | 44 00 | 192 | 48 00 | 79 | 51 00 | 66 | 54 00 | 58 | 56 00 |
| 4" | 226 | 29 00 | 139 | 37 00 | 108 | 42 20 | 89 | 46 00 | 73 | 50 00 | 62 | 52 00 |
| 5" | 392 | 20 00 | 182 | 30 40 | 124 | 37 20 | 100 | 42 00 | 79 | 46 00 | 67 | 49 00 |
| 6" | ∞ | 00 00 | 244 | 25 30 | 149 | 32 00 | 115 | 38 00 | 87 | 42 00 | 72 | 46 00 |

STEAM TURBINES AND TURBINE TESTING.

BY L. A. SHELDON, '05. GENERAL ELECTRIC CO.

In designing any machine we cannot rely entirely on theoretical data and formulae. Although these of course play an important part it is not safe to trust entirely to such information for theory and practice do not necessarily coincide. Many things look well on paper, but when actually built and tried do not come up to expectations. This is often the case when experimental data is lacking or incomplete. The steam turbine is perhaps as dependent upon experimental data for its success as anything else.

The idea of the turbine is very simple. Steam impinges on vanes or buckets on the outer circumference of a wheel and causes it to revolve. The main difficulty experienced is due to the high velocity of the steam. Suppose we expand from 175 pounds gage down to 28 inches vacuum. The steam will assume a velocity of about 4,000 feet per second. Assuming that the most efficient wheel velocity is approximately one-half of the jet velocity, you will see at a glance that the wheel velocity is beyond the limits of practicable mechanical construction. No wheel could revolve with a rim speed of 2,000 feet per second and stay together long.

De Laval used a single wheel with one or more jets of steam and by making his wheel very thick near the hub, and arranging the shaft so that it was flexible between the bearings, permitting the wheel to rotate about its center of gravity, he was able to get very high speeds. Intermediate gears were then necessary to bring the speed down to working limits.

Parsons used the reaction type of turbine having one set of nozzles and a great many moving and stationary blades, the steam expanding as it passed from one to the other. This necessitated very small buckets at one end and very large ones at the other. It also gives considerable end thrust which is taken care of by having a drum or dummy without buckets and the size of the wheel revolving with it as a counter balance.

The Curtis turbine has the process of expansion divided up into stages. Each stage has a set of nozzles and two or three

wheels with stationary blades between them. The steam being expanded in each stage through only a portion of the whole range, does not attain such high velocities and hence the turbine can be run at a much lower speed without materially affecting its efficiency. Increasing the number of stages will increase the working efficiency of the steam up to a certain point where the increase in rotation loss due to the added stage more than equals the gain in efficiency. The larger Curtis turbines built by the General Electric Co. are five stage machines with a bucket speed of 460 feet per second.

Now in designing our turbine let us take for example a machine of the Curtis type. (The other types would present some slight variations.) The first thing that confronts us is a matter of angles both in the nozzles and wheels. The steam must always enter the wheels without shock. Then comes the size of nozzle. Of course this depends to some extent on the power to be developed, but each nozzle must not be too small or the nozzle friction will be excessive. Then comes the matter of clearances, of pitch of buckets, of bucket heights, of radial clearance so that the steam will not spill over the side of the bucket. Then too we must find out how many wheels to use per stage, the most efficient speed, etc. It will be seen at a glance that here is a vast amount of work for the tester. Of course some of this can be calculated or estimated, but these calculations should be carefully checked up by test. To do this it is well to have a small machine in which different wheels and nozzles, and combinations can be tried out under different conditions of speed and different ranges of pressure. It goes without saying, that the tester must of necessity be extremely accurate. He must at all times know the exact assembly of the machine. He must be sure of the alignment of wheels and intermediates and of course all instruments used must be carefully calibrated so that there can be no doubt as to their accuracy. He should at any time if called upon to do so be able to check his tests within one per cent.

Since the rotation loss of our experimental machine will be a much larger percentage of loss with a small load than with a large one it will be well to deduct this in our comparisons. This can easily be done by having an auxiliary turbine to which just enough steam is supplied to keep the machine at the desired speed. Then all the steam which goes into our main turbine will come out as work at the brake and we can easily figure our

bucket efficiency. That is the efficiency independent of the friction of the machine.

Complete tests on rotation loss will also be desirable. Wheels having different bucket heights, etc., can be run in an atmosphere of steam at different pressures and the former necessary to rotate them noted in each case. From these tests formulae for rotation loss can be readily deduced.

Having now our data we should be able to go ahead and design our turbine intelligently. From our tests we have found say a two wheel combination to give the highest efficiency and this is say under five stage conditions. So we will build our machine with five stages and two wheels per stage having as near as possible the same amount of work produced per stage. To do this it will obviously be necessary to leave a greater available energy for the first stage than for the other stages as the first stage will revolve in steam of about 50 pounds gage, so that the rotation loss will be quite large. The other stages which are revolving in steam of very low pressure or else in high vacuum have a very small rotation loss and hence will not give us much trouble. It may be best to design the first stage as a four stage machine and the other four as a five stage machine or perhaps the second stage should have a little larger proportion of work assigned to it. You can readily see that a great many good combinations can be arranged and only very careful consideration will determine which is best. Even after our machine is built we can sometimes vary our stage pressures and effect a considerable gain. Any gain even though slight will save a good many dollars on the coal pile in a year's time.

Thus it will be seen that the tester is quite necessary not only in building turbines, but also in testing the finished machine so that the customer may know that he is getting what he pays for.

The steam turbine is without doubt the steam engine of the future. Its operation is simple and it gives very little trouble while in economy and range of operation it is much superior to the reciprocating engine. The best water rate ever produced by any steam engine was on an 8,000 K. W. Curtis Turbine at the Fisk street station of the Chicago Edison Co., which in test delivered to the switchboard 8,000 K. W. at a steam consumption of 12.8 pounds per K. W. hr. This is an equivalent of about $8\frac{3}{4}$ pounds per I. H. P.

NOTES ON THE DESIGN OF ORE-HANDLING BRIDGES.

ALFRED BOYD, INSTRUCTOR IN CIVIL ENGINEERING.

The annual production of steel in this country is more than ten million tons. This large output has been made possible by improvements in all the processes of production from start to finish. It is nowhere more noticeable, probably, than in the methods of handling the ore. When we consider that four-fifths of the iron ore taken out in this country comes from the Lake Superior mines, and is transported five or six hundred miles by lake boat and railroad car to the furnaces, being reloaded several times, it is evident that only the most economical handling makes it possible for the steel trust to sell its product at present prices and still pay a very decent dividend.

The appliances for loading and unloading this ore, and for manipulating the finished product are exceedingly interesting from the standpoint of the mechanical engineer, calling for the exercise of all his skill, ingenuity and resourcefulness. It is to some of their structural features, however, that I wish to call attention. This article will be confined to ore-handling bridges and some of the interesting points in their structural design. They can be seen at any of the lake ports where ore is transferred from boats to railroad car or stockpile, and at various points in the interior where it is again rehandled before charging in the furnaces. They differ in design according to location and work to be done, and according to the individual fancy of the designer.

In all of these the ore is handled by means of a bucket which is hoisted and moved to and fro across the bridge. The bridge also has a movement at right angles to its length. There are thus three motions to provide for: 1. Hoisting. 2. Trolleying. 3. Bridge travel.

Most of the unloaders of the bridge type may be divided roughly into two classes. In the first all the operating machinery is placed in the machinery tower, and all the movements of the bucket and trolley are controlled by ropes passing over sheaves. In the second, the operator travels with the trolley, and the ma-

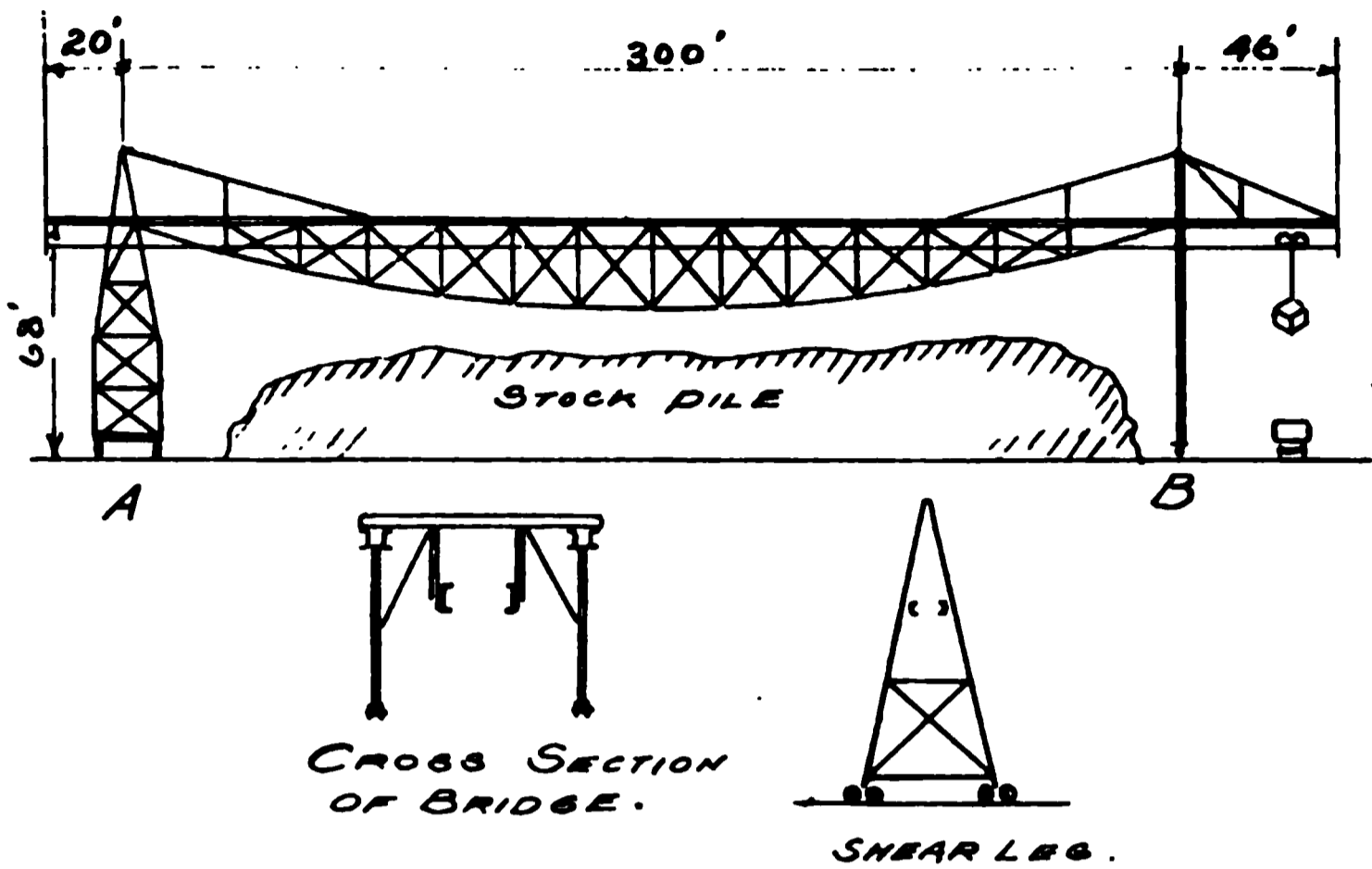


FIG. 1. MOVING LOAD, 10 000 LBS.
ROPE-DRIVEN TROLLEY.

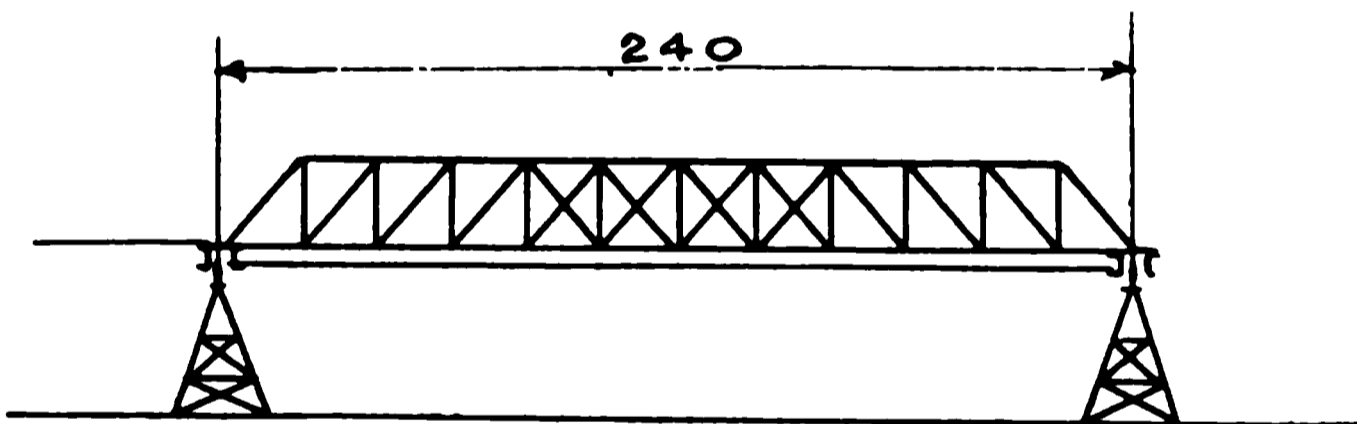


FIG. 2

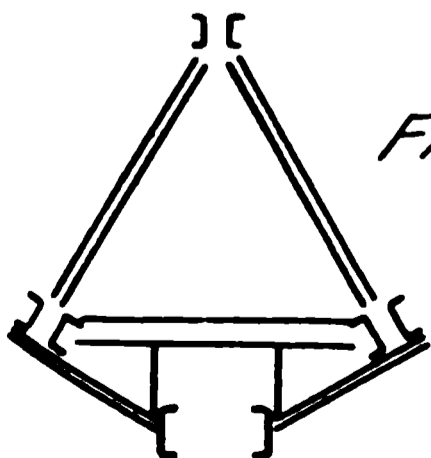
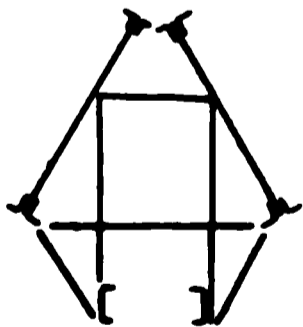


FIG 3.

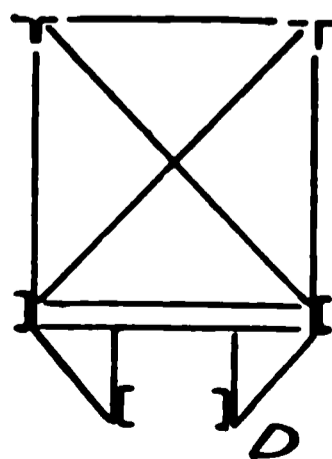


FIG 4.



chinery for manipulating bucket and trolley moves back and forth across the bridge. Each of these systems has its advantages. In the second the operator has at all points an unobstructed view of the bucket and better control of its operations; but, on the other hand, the moving load on the bridge is greatly increased, requiring a much heavier structure. Where the operator travels with the load, the power is supplied by means of electric wires traversing the bridge from end to end. The cab containing the controllers, and in which the operator stands, is attached to the trolley frame.

Several of the more usual types of structures are shown diagrammatically in figures 1, 2, 5, and 6.

The stresses coming upon the various parts of the bridge and its supports are divided as follows:

1. Dead load stresses due to the weight of the structure.
2. Live load stresses due to the moving trolley and its load.
3. An allowance for impact.
4. Wind stresses.
5. Pull of the ropes (with a rope-driven trolley).
6. Tractive effort of trolley on track (with an electrically driven trolley).
7. All stresses due to the machinery, reactions of shaft supports, bridge drive, etc.

The dead load weight of the bridge per lineal foot ranges between 100 and 400 pounds in most cases, depending on span and amount of moving load. If we have not the weight of similar structure already built with which to make comparison the following formula may be used to determine the approximate weight per foot.

$$w = 100 + \frac{W}{150 - l}$$

In which w = wt. of steel in bridge per foot of span.

W = wt. of loaded trolley not including impact allowance.

l = length of span in feet.

This should be checked with the weight of the complete design, and correction made if there is too great a variation.

The moving load on the bridge varies from 3,000 pounds to 30,000 pounds, depending upon the capacity of the bucket, and on whether the trolley is rope driven or self propelled. In the latter case, the moving load includes, besides the weight of the

loaded bucket, the weight of motors, gears, hoisting drums, controllers, cab, and trolley frame.

For determining the allowance for impact the following formula is perhaps as rational and easy of application as any:

$$I = L \times \frac{L}{L + D}$$

where I = allowance for impact

L = live load stress

D = dead load stress

The computation of the live load stresses, by finding the maximum moments and shears, presents no especial difficulty. The live load is, in general, divided between two axles. The maximum live load shear in any panel occurs when one of these axle loads is at the adjacent panel point. In trusses with polygonal chord, like the inverted bow-string truss shown in figure 1, this shear is divided between the web and inclined chord member. This truss is one that is frequently used with a rope driven trolley. The counters, it will be noticed, extend across the entire span. In the truss shown in figure 1 the vertical members are made of gas pipe, varying in diameter according to stress and ratio of length to radius of gyration. The top chord is composed of two laced channels, the bottom chord of flat plates, the diagonals of round rods with turn-buckles. One advantage in the use of the gas-pipe struts and round rods is that they decrease the effect of wind pressure.

The floor-beams from which the track is hung also serve as struts in the top lateral system. There is no bottom lateral bracing in this case, the construction being similar to an inverted pony truss. Sometimes the track on which the trolley runs is suspended below the trusses, instead of between them, as in the instance just mentioned. This permits of both top and bottom diagonal bracing, and gives a stiffer construction. A cross section of this type is shown in figure 4. Sometimes the two trusses are inclined so as to form the two sides of an equilateral triangle, thus having but one top chord. This is illustrated in figures 2 and 3. In figure 3 the vertical struts and diagonal rods are connected to the chords at the panel points by means of steel castings. In figure 2 the angles forming the top chord are joined by means of a curved trough-shaped plate. One objection to this triangular arrangement is the inefficient bracing of the compression chord, an objection which prejudices most

designers against the pony truss in railway bridge construction. Sometimes the bottom chord is also made to serve as a track for the trolley, as in figure 8. The fiber-stress due to the bending must then be added to the direct tension, to determine the maximum stress. In this case, however, the effect of continuity should be considered, thus cutting down the effective span.

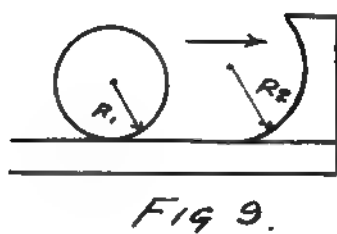
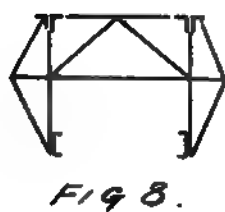
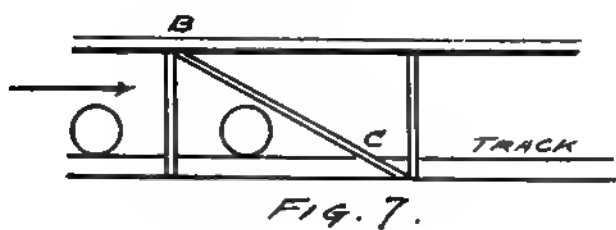
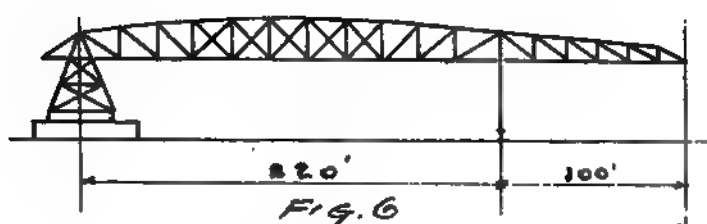
In any case, whether the wheels run directly on the bottom chords or on tracks suspended below them, there must be efficient track bracing to take care of the lateral thrust of the load. That this thrust may be considerable is evident from the following computation. Figure 4 shows a cross section of a truss in which the trolley runs on a track suspended below. Assume weight of trolley and load at 20,000 pounds, and that the bridge is moving in the direction indicated by the arrow, at a speed of 300 ft. per minute. Suppose that the bridge is stopped and brakes set, so as to bring structure to rest in a distance of 10 feet. Three hundred feet per minute equals 5 feet per second. The energy of the loaded trolley in the direction of bridge travel

$$E = \frac{Wv^2}{2g} = \frac{20,000 \times (5.)^2}{64} = 8,000 \text{ ft. lbs. approx. Assume that}$$

the wheels are single flanged and that this load is brought to rest by the pressure of its track on the wheel flanges at point marked *P*. If this pressure acts through a distance of 10 feet its average amount = $8000 \div 10 = 800$ pounds. This is the force to be considered in determining lateral strength of top flanges of track stringers and strength of track bracing.

The track must also be braced longitudinally. In figure 7 assume the moving load at 20,000 lbs., coefficient of friction of the wheels on rails at .20. Then the force $F = .20 \times 20,000 = 4,000$. which is the longitudinal thrust, divided between the two tracks, giving 2,000 pounds as the horizontal component of stress in one track brace. If the tracks are provided with rail stops, the bracing should be made strong enough to resist the shock of the loaded trolley striking the stop when going at full speed, as this is likely to occur, though a careful operator will avoid such shocks. These stops (see figure) are usually made curved, either of steel or cast iron, and bolted to the track. The radius of the curve is greater than the radius of the wheel-tread, so that the wheel mounts the curve instead of striking it directly, (see figure 9.) The force of gravity is thus made to assist in bring-

FIG. 5.



ing the load to rest. If W = weight of moving trolley and load, in pounds, v = its velocity in feet per second; then the energy in the moving body =

$$E = \frac{Wv^2}{2g}$$

If one-half of the total weight is on the two front wheels, then the distance, d , which these wheels will have to be raised in order to bring the body to rest

$$d = \frac{Wv^2}{2g} \div \frac{W}{2} = \frac{v^2}{g}$$

If the trolley were moving 5 feet per second when it hit the stop, the distance

$$d = \frac{25}{32} = .781 = 9\frac{3}{8} \text{ inches.}$$

In cases of high trolley speed, it is not practicable to consume all of the energy in this way, and the stop and track bracing must be made strong enough to withstand the blow.

There is also another class of stresses to be provided for. Where the bridge is driven from machinery at one end, there is a shaft passing across the bridge and down the shear leg with universal couplings and bevel gears, to the trucks of the far end. On account of the torsion of the shaft or the unequal slipping of the wheels on the rails, one end of the bridge is likely to advance ahead of the other, thus introducing stresses at the connection of bridge to tower and shear leg. In figure 1 this is avoided by the use of a pivoted saddle, allowing rotation, and also permitting the shear leg to incline slightly from the vertical. In cases where the span is comparatively short the structure is made perfectly rigid, and the bracing must be made stiff enough to resist this distortion, as in figure 5.

In connection with the details for all steel work carrying machinery, it should be kept in mind that mere provision for the static loads carried is not sufficient. Standard connections for beams and channels are seldom adequate. Care should be taken to secure rigidity in all directions in which the shock or jar of machinery tends to produce distortion.

Structures of this kind are undergoing constant change and improvement. The purpose of this paper, which is far from exhaustive, has been to describe some of the common types and to suggest some of the problems which confront their designer.

PRESENT APPLICATIONS OF THE COOPER-HEWITT MERCURY RECTIFIER.

BY J. B. GIBBS, '05. WESTINGHOUSE ELEC. AND MFG. CO.

The problem of getting direct current from alternating current has been an important one ever since the advantages of alternating currents for power distribution have been recognized. Until recently, the only solution of the problem was by means of rotary converters or motor-generator sets, and the announcement of a static rectifier for alternating currents opened the way for large economies in certain directions. In its present state of development the mercury rectifier does not compete with the rotary converter or motor-generator set where large currents are to be handled; but for small currents at any voltage it shows results considerably better than the revolving machines.

In what follows, it is attempted to give a description of two commercial applications of the mercury rectifier. Theoretical questions are touched upon only in so far as is necessary to make the action of the apparatus clear.

The rectifier proper is a large glass bulb from which the air has been exhausted. It contains a small amount of mercury, and is provided with the necessary terminals. The negative electrode passes through the glass at the bottom of the bulb and connects to the mercury inside, and the two positive electrodes are fused in the glass at the top or sides. At the low pressure which obtains in the bulb, a part of the mercury is vaporized and forms a conducting path between the electrodes. The utility of this device lies in the fact that, when no current is flowing, the surface of the negative electrode is the seat of a very high resistance, which disappears as soon as a current is started. No such resistance is offered at the surface of the positive electrode. The action is as though a check valve were placed on each electrode, permitting the free passage of current from electrode to the vapor, but preventing the passage of current from the vapor to the electrode. When a bulb is in operation, it may be conceived that the valve on the lower terminal is broken, while those on the two upper terminals are working normally. Current then flows freely from either of the upper electrodes to the lower, but cannot flow in the

opposite direction, nor can it flow from either of the upper electrodes to the other.

To start the bulb, the high negative electrode resistance must be broken down at the surface of the mercury, and this may be accomplished in any one of several ways.

If a sufficiently high voltage be applied to the bulb, the negative electrode resistance will be broken down and a current will be started; but at the instant when the current starts the resist-

Fig. 1

ance of the circuit will fall from a very high value to a very low one, comparatively, and the result will be a rush of current which will destroy the bulb. Bulbs are occasionally broken in service by an abnormal rise of voltage which starts a short circuit between the two positive electrodes.

Another way of starting is to put a band of tinfoil around the outside of the bulb at the height of the surface of the mercury and connect it to one of the upper terminals. A static charge is thus induced on the surface of the mercury, and, if the differ-

ence of potential is sufficient, the negative electrode resistance is broken down and a current is allowed to start.

A third method is to design the bulb with two pockets at the bottom. Each is nearly full of mercury and has an electrode fused in the glass. A low voltage is connected between these two terminals, and the bulb is tilted until mercury flows from one pocket to the other. When this momentary short circuit is broken a spark is produced which breaks down the negative electrode resistance and allows the current to start. The low voltage referred to is often furnished by a small starting transformer designed to give a limited current when its secondary is short circuited.

The last method of starting is the one generally used, and is the most reliable, although the second method is sometimes employed.

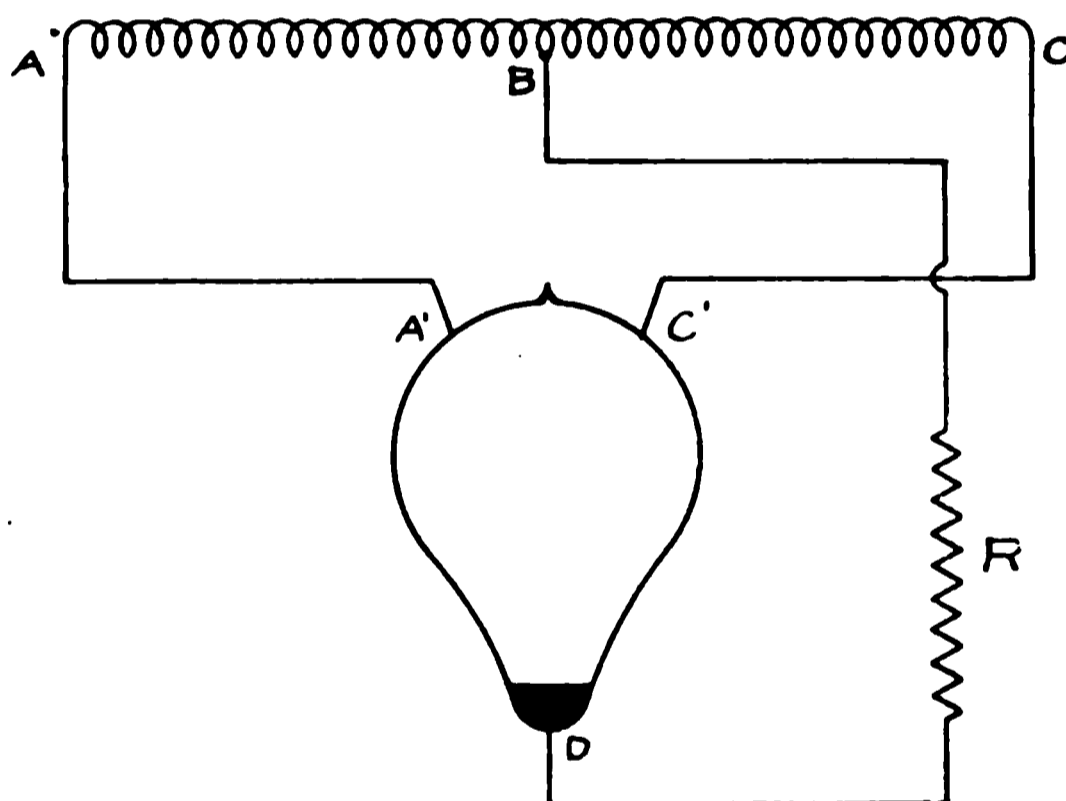


Fig. 2.

Figure 1 shows a bulb for use on high tension circuits. The positive electrodes are enclosed in glass tubes bent at an angle and open at the end, the object being to make a long path between the two positive electrodes and to lessen the liability to short circuit. The bulb has two electrodes at the bottom, and is started by tilting.

Figure 2 shows the connections between a rectifier bulb and its load. Suppose A B C to be the secondary winding of a transformer connected to the bulb as shown, and suppose that by some means the negative electrode resistance at the surface of the mercury electrode, D, is continuously broken down. Then at the

instant when C is positive and A is negative, current will flow from C' through the bulb to D and back through the external circuit, R, to B. At the next instant, when A is positive and C is negative, current will flow from A' through the bulb and external circuit and back to B. No current will flow toward either A' or C' in any case, because of the high resistance at the surface of whichever one is negative. Thus the current in the external circuit is always in the same direction, while the two halves of the transformer winding work alternately, each half delivering an impulse downward through the bulb while the other half is idle. The shape of the electro-motive force wave in

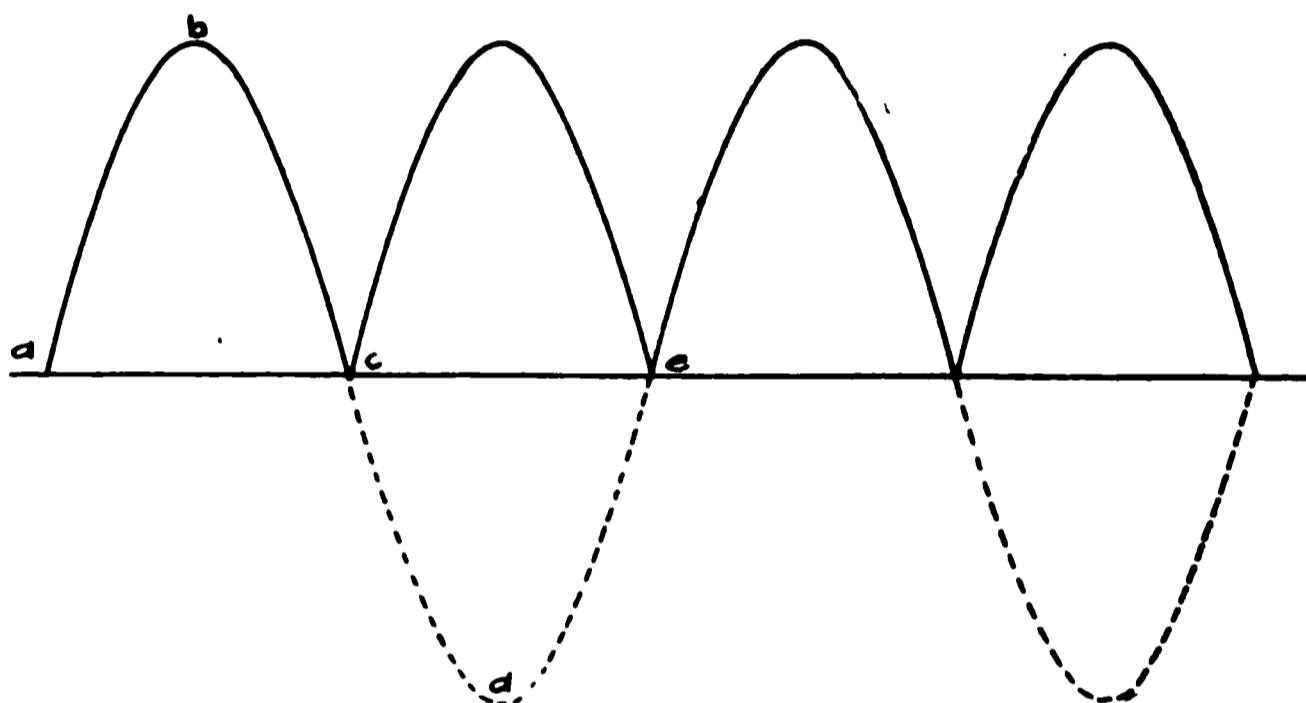


FIG III

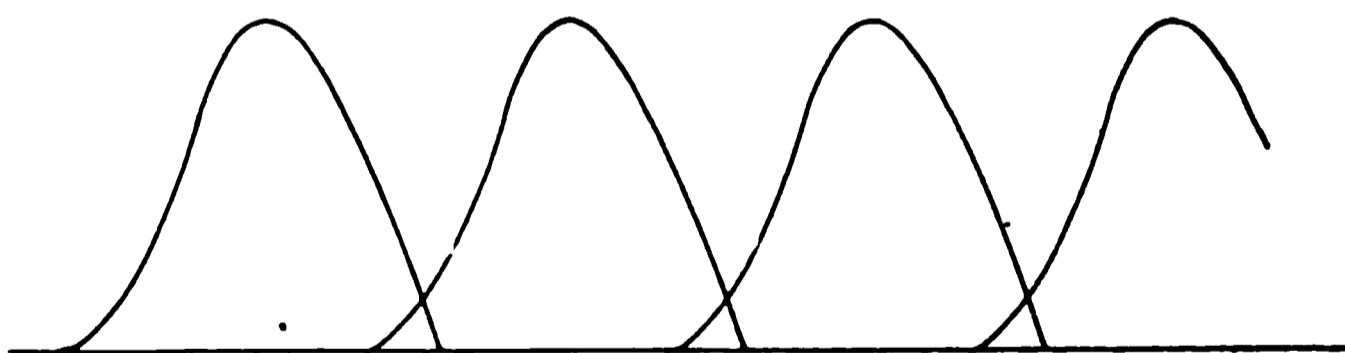


FIG IV



FIG V

the circuit D B, neglecting the effect of bulb resistance, is shown in figure 3 where a b c d e, etc., is the electro-motive force between A and B or between B and C, figure 2. It is seen that the effect of the rectifier, so far as the circuit, R, is concerned, is merely to reverse the negative half of the alternating wave.

If, however, the current through the bulb falls to zero, as at c and e, figure 3, the high negative electrode resistance is instantly re-established at the surface of the mercury, and the bulb ceases to operate, or "goes out." To prevent this, means must be found to make the discharge of energy through the bulb continuous.

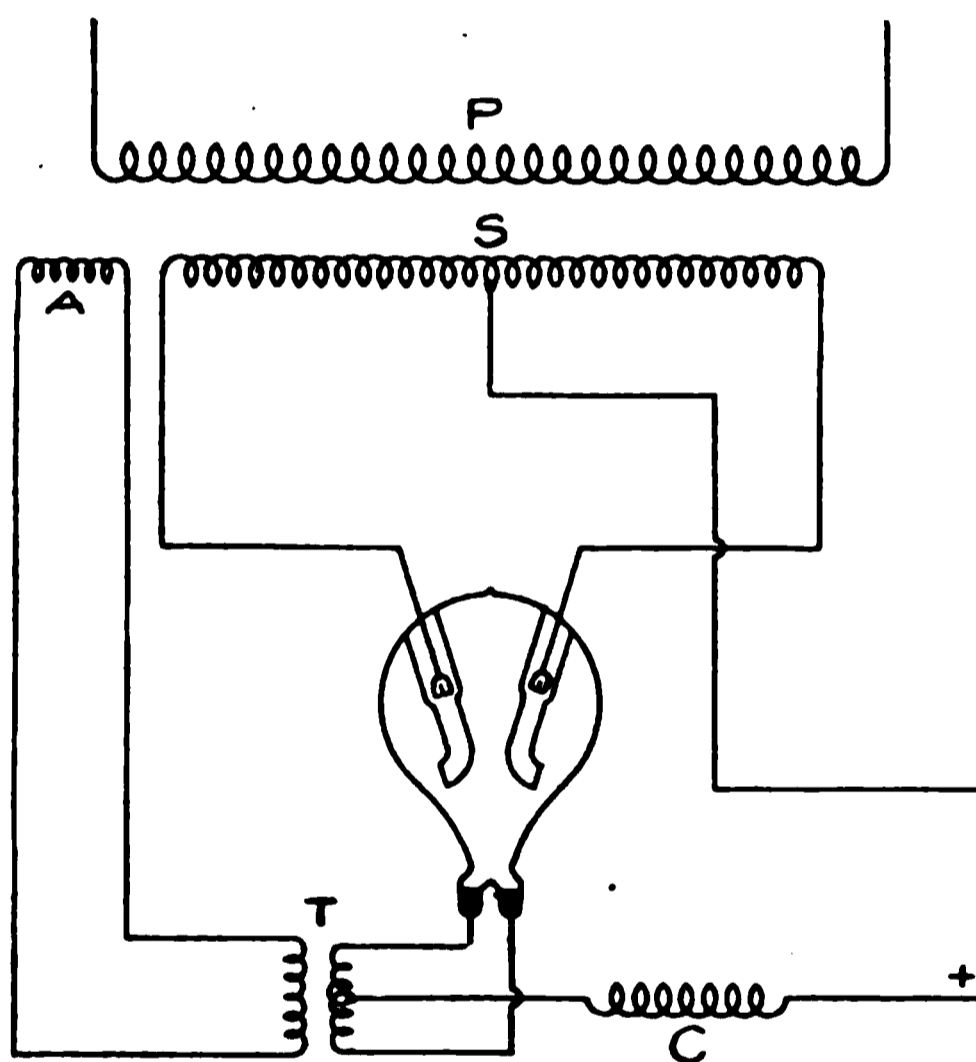


Fig. 6.

If the electro-motive force shown in figure 3 be applied to a circuit containing inductance, the current will rise more slowly than the electro-motive force, reach its maximum later, and die out more slowly. Figure 4 shows such a current. Each wave is held over, or sustained until after the next has started, and the resultant current, shown by figure 5, never reaches zero. This end may be attained by inserting a reactance, or "sustaining coil" in the direct current circuit, or by a special arrangement of the coils in the transformer. The sustaining coil stores energy during the period of maximum current and restores it to the circuit during the period of minimum current, and the larger the induct-

ance of the sustaining coil, *i. e.*, the larger the amount of energy stored and restored, the more nearly uniform will be the value of the direct current. This becomes an important consideration if the rectifier is to be used in connection with a lighting system, as the lights will flicker if the fluctuations of the rectified current exceed a limited amount.

Fig. 7.

The principal uses of the mercury rectifier, at present, are for running direct current arc lamps and for charging storage batteries.

DIRECT CURRENT ARC LIGHTING.

By far the most efficient lamp now on the market for street lighting is the metallic flame arc lamp. It is essentially a direct

current lamp, however, and must be run from constant current D. C. generators or from a constant current rectifier outfit.

The efficiency of a constant current D. C. generator is in the neighborhood of 80%, and if driven by an induction motor, as is usually the case in large plants, the efficiency of the two machines is about 70%. The efficiency of a constant current rectifier outfit for the same service is from 89% to 92% according to size.

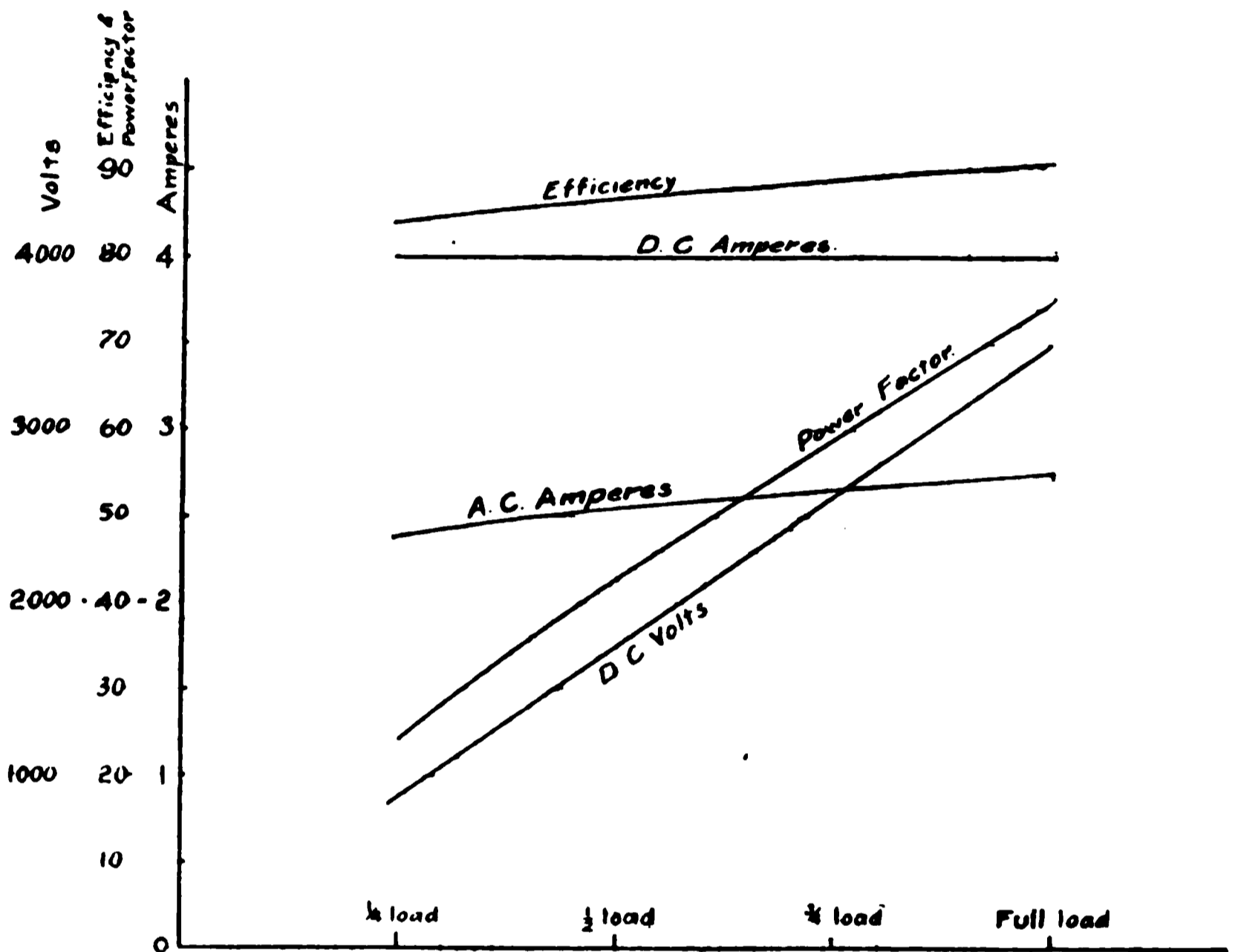
Fig. 8.

A comparison of the energy required for several lighting systems follows. It is assumed that alternators are the source of power in all cases, and the efficiencies given above are used.*

| System. | Watts at lamp terminals. | Watts per lamp at A. C. bus bars |
|---|--------------------------------|--|
| D. C. 9.6 amp. open arc, motor and generator. | 480 | 685 |
| D. C. 9.6 amp. open arc with rectifier..... | 480 | 535 |
| D. C. 6.6 amp. enclosed arc, motor and generator..... | 480 | 685 |
| D. C. 6.6 amp. enclosed arc with rectifier..... | 480 | 535 |
| A. C. 7.5 amp. enclosed arc..... | 475 | 495 |
| D. C. 4 amp. metallic flame arc with rectifier | 275 | 305 |

*See article by C. E. Stephens, Electric Journal, October, 1907.

It is thus seen that the metallic flame lamp with rectified alternating current saves about 40% of the energy required by its closest competitor, the enclosed A. C. arc, while the substitution of rectifiers for constant current generators and induction motors, in plants running D. C. arcs, will save about 20% of the energy expended at present: so the method of applying the rectifier to this service becomes a question of interest.



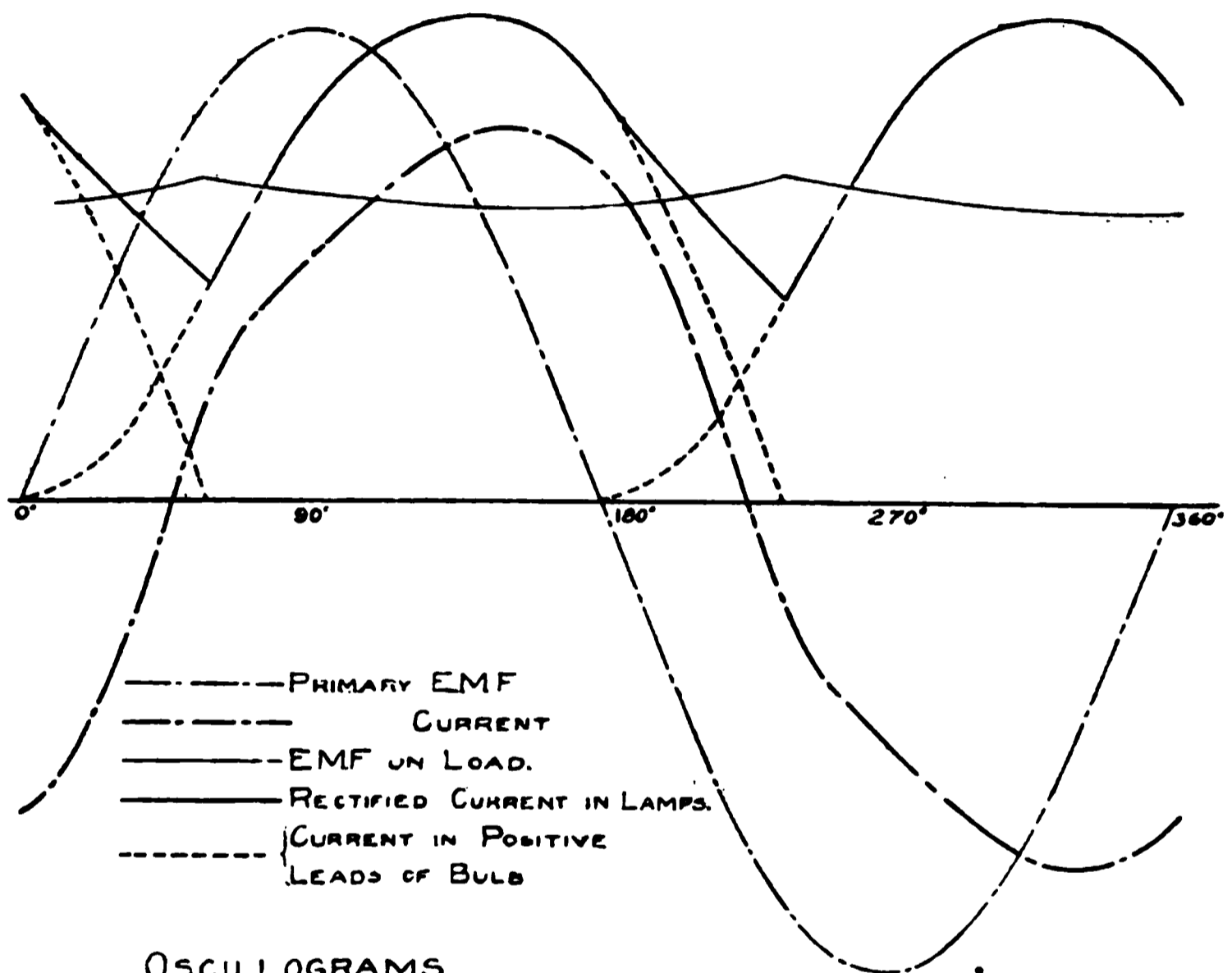
PERFORMANCE CURVES.
4 AMPERE CONSTANT CURRENT RECTIFIER.

FIG IX

An ordinary constant current regulating transformer consists of stationary and movable coils on an iron core. When current flows, the coils are repelled from each other with a certain force, depending on the current, and this force and the weight of the moving coil are balanced by a counterweight. Suppose that the resistance of the secondary circuit be decreased, as when one of the lamps is short circuited. The current tends to rise, but this increases the repulsion between the coils and they move

farther apart. This, in turn, increases the area of the path for magnetic leakage between the coils, and the induced voltage in the secondary is decreased until the current comes back to its normal value.

Such a transformer may be adapted for use with a mercury rectifier by bringing out a tap from the middle point of its secondary coil. A small starting transformer for the rectifier bulb and a sustaining coil must also be provided.



OSCILLOGRAMS

FROM

4 AMPERE CONSTANT CURRENT RECTIFIER

FIG X

Figure 6 is a diagram of this arrangement. P and S are respectively the primary and secondary windings of a constant current regulating transformer. T is a small starting transformer with the ends of its secondary winding connected to the two terminals at the bottom of the rectifier bulb, and the middle point connected, through the sustaining coil, C, to the positive side of the direct current circuit. The primary of the starting transformer is connected to the auxiliary coil, A, on the regulator, and the negative side of the direct current circuit is connected to the middle point of S. For high voltages D. C. two rectifier bulbs in series are used.

Figure 7 shows the interior of a 75-light rectifier outfit manufactured by the Westinghouse Electric & Mfg. Co. The two bulbs are held in wooden boxes supported from the frame of the regulating transformer. The terminals of the bulb are wired to contacts in the base of the box and there are corresponding contacts on the strips which support the box so that the bulb is connected to its circuits by setting the box in place. In the photograph one of the boxes is raised slightly to show the contacts on which it rests. The regulating transformer is designed so that no sustaining coil is necessary.

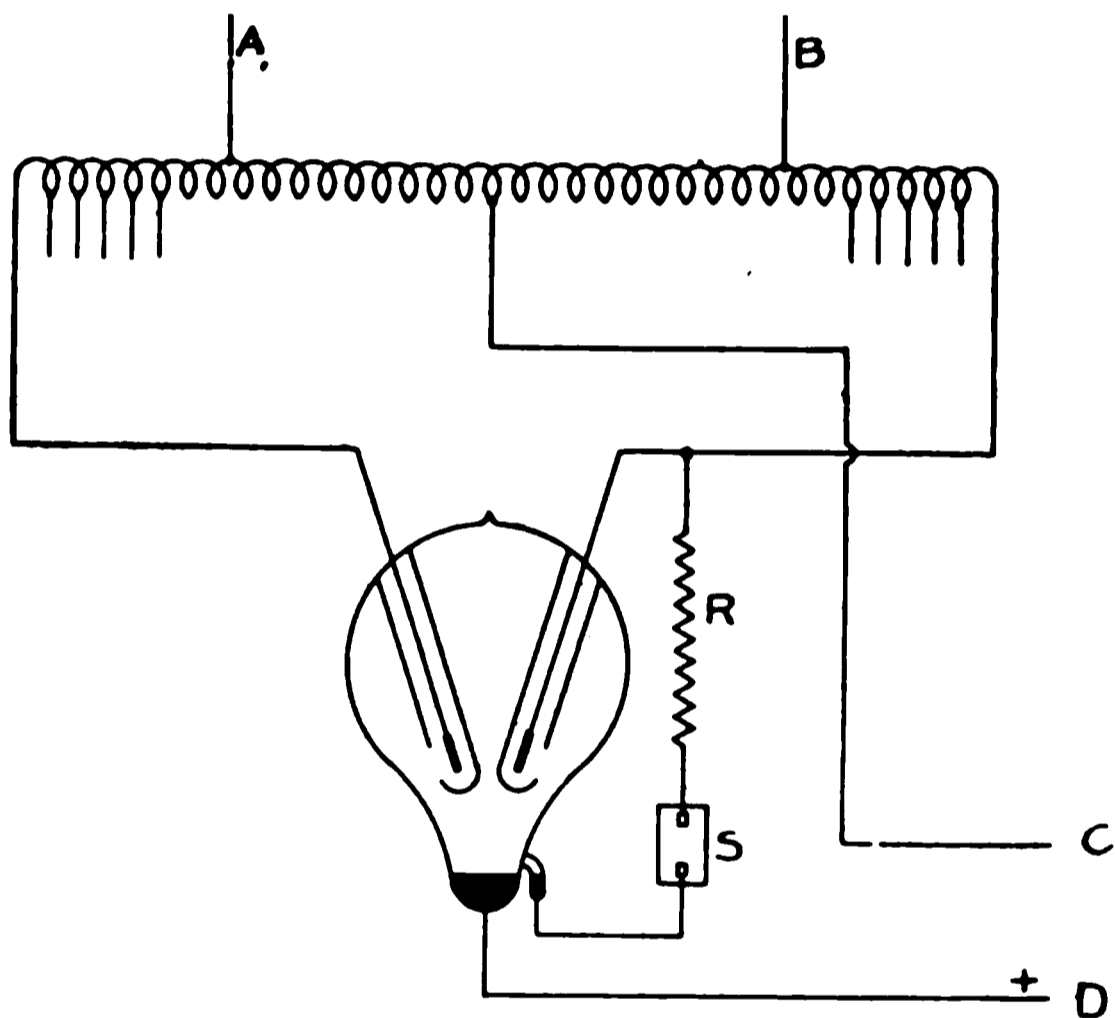


Fig. 11.

Figure 8 is a view of a 50-light outfit made by the same company, complete with its tank. If constant potential alternating current is fed to leads A and B, constant direct current will be delivered from leads C and D. This entire line of rectifiers is oil cooled.

Some typical curves are shown in figures 9 and 10. Those in figure 9 are plotted from tests on a 50 lamp, 4 ampere D. C., 60 cycle primary, rectifier; and figure 10 is plotted to scale from oscillograms taken on the same outfit.

BATTERY CHARGING.

Rectifiers for charging storage batteries present no features essentially different from those found in the arc lighting outfits.

For this service comparatively large currents and low voltages are required and the form of the bulb is modified somewhat. As there is very little danger of short circuits at the voltage used, the terminals are placed closer together than in the high tension bulbs, and they are larger on account of the larger currents. The starting voltage is usually provided by connecting one of the upper terminals of the bulb, through a high resistance and a switch, to the starting terminal.

In charging batteries, both the current and voltage should be under control, and as the cheapest and most convenient means of accomplishing this, an auto-transformer is employed. It is designed for connection to a commercial lighting circuit, and is provided with taps for varying the voltage supplied to the bulb. No separate sustaining coil is necessary, as its function can be incorporated in the auto transformer.

Figure 11 is a diagram of a battery charging outfit. The A. C. line is connected to the leads A and B, and the battery to be charged is connected to C and D. R is the starting resistance and S, the starting switch.

This method of battery charging is replacing other methods and bids fair to have almost a monopoly of the field on account of its economy, convenience, and reliability.

THE STUDENTS' COURSE AT THE ALLIS-CHALMERS COMPANY'S WORKS.

BY A. G. WESSLING, SUPT. OF APPRENTICES.

On account of the great variety of products manufactured by Allis-Chalmers Company, its student apprentice course is divided into two branches. The company offers a course in mechanical engineering at its Milwaukee shops and a course in electrical engineering at its Cincinnati shops. Both courses have been carefully arranged in such a manner as to give the student such shop training as may be of greatest service to him in his future work, while the time devoted to this purpose is limited to two years.

The work in the mechanical department includes practical experience in the regulator and governor departments on the assembling and erecting floors, and in the gas engine and steam turbine departments.

At the Cincinnati works the student is employed in the commutator, controller, assembly, erecting, winding, and testing departments, devoting about three months each to the first four departments and the rest of the time to the last two departments.

As a rule most students are always anxious to get out of the department in which they are working and into some other department. They do not seem to know what they want to get out of their course, nor what particular use it will be to them to understand the work of this or that department. It would be well if such students would take the advice of those whose experience has taught them the value of such an apprentice course, and would take it for granted that this training, simply as a training, will be as much a benefit to them as their course in mathematics is essential as a part of their proper training while at college. The student should realize that, in such a students' course, he has an opportunity for becoming intimately acquainted with ordinary shop men, with the complicated systems of shop routine, and with up-to-date methods of manufacturing on a large scale. Such opportunities cannot be had in any other way, and if the young man graduating from college neglects the opportunity then, he will realize his loss only in after years when

he feels that he cannot afford the time required to take up such a course.

It is questionable whether any engineer would say that his knowledge of some particular science or branch of mathematics has been of special value to him in his engineering work. He simply knows that the mental training he received while pursuing the course in calculus, for example, aided materially in his development and is of daily service to him in his work. So the man who has taken a student apprentice course in the shop is unable to say that the work in any one department of the shop was of greatest benefit to him, but he appreciates the fact that the training he received prepared him for the duties to which he was later assigned.

Interior University Power Plant.

THE COMPUTATION OF BACKWATER.

O. V. P. STOUT, PROFESSOR OF CIVIL ENGINEERING.

The following is proposed as a basis for the computation of backwater caused by dams or other obstructions in flowing streams. Referring to Figure 1, which represents a longitudinal section of the stream, we have:

h = the increased depth at any point, due to backwater.

S = the original slope of the water surface at the same point.

s = the slope of the water surface at the same point after this surface has been raised by a dam or other obstruction.

L = the distance from the dam or other obstruction to the same point.

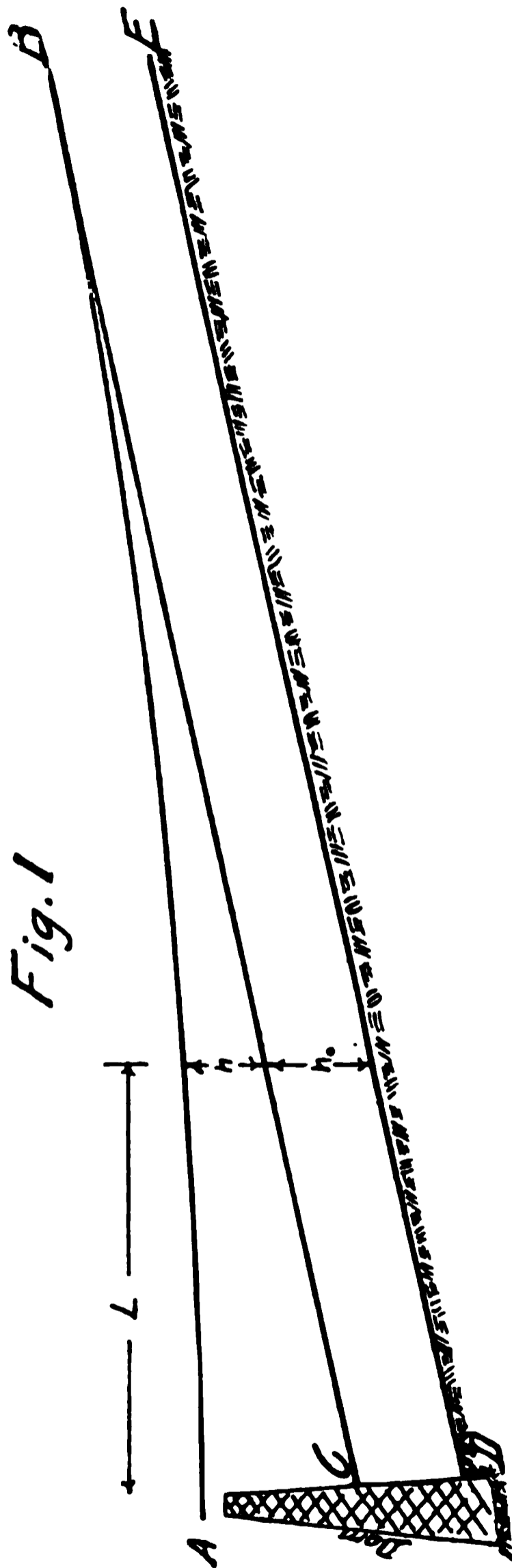
The following relation is apparent, being true at any point:

$$dh = -(S - s)dL, \quad \text{from which}$$

$$-dL = \frac{1}{S-s} dh$$

Now if a curve can be drawn such that the coordinates of any point on said curve are h and $\frac{1}{S-s}$ respectively, L will be represented by the area bounded by the curve, the axis of h , and lines drawn perpendicular to the axis of h through the points on that axis which correspond to h at the dam and the value of h for which L is to be determined, respectively. Figure 2 shows such a curve drawn for the simple case of a channel of uniform grade and cross-section. It is of course asymptotic to the axis upon which $\frac{1}{S-s}$ is measured. If produced upward it will be asymptotic to a line parallel to the axis of h and distant $\frac{1}{S}$ therefrom.

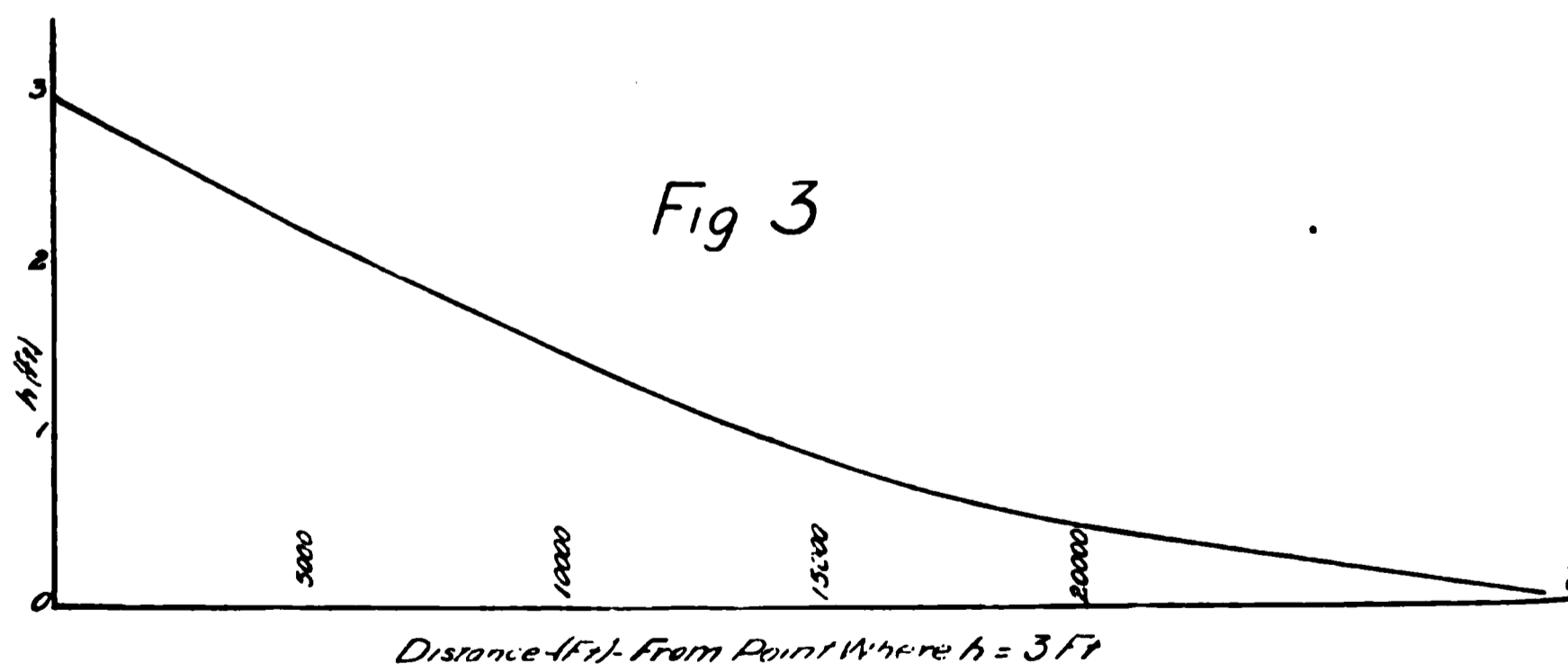
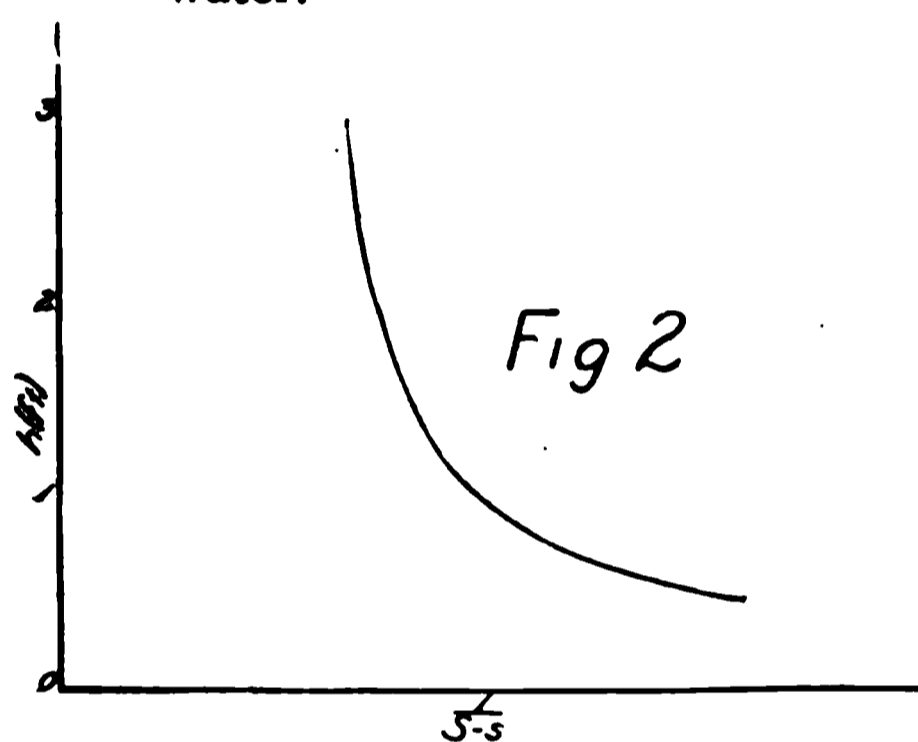
If h at the dam is given and it is desired to find the distance from the dam to the point at which h has a given value, it is plain that the problem can be solved directly by integration to ascertain the above described area. If, however, it is desired to know the height of the backwater at a given distance from the dam, the problem must be solved either by applying a cut and try process to figure 2, or else figure 2 may be used to obtain the



ata for the construction of the curve in figure 3, from which h or any given value of L may be read directly.

For the case of a channel of uniform grade and cross-section

the computations preliminary to the construction of figure 2 are simple. We have given: discharge = q , depth of unobstructed flow = h_0 , and S = the grade of the bed of the channel, a constant; and we are required to find s and therefrom $\frac{1}{S-s}$ for successive values of total depth = $h_0 + h$. The problem assumes this simple form in the case of checks or dams in a canal, and in those cases in which the absence of complete surveys on a natural stream makes it necessary to assume conditions of uniformity in order to make approximate computations of back-water.



If the channel is a natural stream, and surveys have been made which give the longitudinal profiles of the stream bed and the water surface for unobstructed flow, and cross-sections of the channel have been taken at frequent intervals of distance, the procedure is as follows: Calculate s at the dam. Assuming this

value of s to obtain until the first measured cross-section above the dam is reached, calculate h at this cross-section. For this section s can now be computed, and assuming it to obtain until the second section above the dam is reached, the computations can be repeated for that section. The process can be extended to other sections in succession. As soon as the computations for a few sections have been made the curve of figure 2 should be plotted and L determined from the figure in order to compare the result of this determination with the actual known value of L at the measured cross-sections. It is not to be expected that they will agree precisely. In any case in which the departure from regularity of natural slope and section is not too extreme, the value of L obtained from figure 2 on the trial construction will be greater than the actual known value. In such case the best method of correction is simply to move up on the curve until a point is reached for which the value of L from the figure is equal to the known value, and take this as the starting point for computations to construct the balance of the curve.

COMMERCIAL CALCULATIONS ON TRANSFORMERS.

C. C. M'DOWELL, '05, POWER AND MINING DEPARTMENT, GENERAL ELECTRIC CO., SCHENECTADY, N. Y.

Some of the methods used in testing transformers and calculating results from test data will be given in this article, without considering any questions of design. The methods of testing described are applicable to large transformers, say 50 Kw. and over. For very small transformers some refinements should be introduced to eliminate errors due to current admitted and power consumed by the instruments.

Commercial tests of transformers are made to determine that the ratio of transformation is correct, the losses and heating not excessive, and the insulation sufficient.

Resistance is first measured, generally after allowing the transformer to stand in the test room for some hours, so that the coils may have the same temperature throughout; careful thermometer readings are taken. The measurements may be made with a galvanometer and bridge, but are often taken with an ammeter and a milli-voltmeter with proper resistance in series with it. Polarity, which is the test used to show whether the corresponding terminals on the several transformers are of the same polarity, is taken while the measure lines are on. With the windings connected in series and current passing through them, the voltmeter lines should be so put on one transformer as to give a positive deflection on the voltmeter; then the voltmeter lines are transferred to the corresponding terminals of the other transformer, the circuit is opened, and if the instrument gives a positive kick polarity is correct. The voltmeter must be protected by sufficient resistance to prevent damaging it. In resistance measurements, especially with high voltage transformers, care must be taken not to break the measure current while the voltmeter is in circuit, to avoid damaging the instrument, or injuring the man holding the measure lines.

Ratio of transformation is determined by sending alternating current of proper frequency through one winding and reading voltage on both windings. In order to get reliable

results at least one volt per turn should be used. Tap ratios may be taken in the same way, though voltage is generally applied to the winding which has the taps on it.

Core loss is taken by applying full voltage at normal frequency to either the primary or secondary winding, depending upon the voltage which suits the alternator used, and reading amperes and volts. An alternator giving a sine wave should be used as the wave form has a considerable effect upon the loss; a peaked wave gives a lower, and a flat wave a higher loss than does a true sine wave. Temperature should be taken, as core loss decreases with rise in temperature. If the core loss is abnormal readings are taken at different frequencies to separate hysteresis and eddy current losses.

Full voltage should not be put on an oil-cooled transformer until it is filled with oil, as the oil greatly increases the insulation resistance.

Impedance, or the volts and watts necessary to force normal current through the transformer, is determined by short-circuiting one winding, generally the secondary, and applying sufficient voltage to the other winding to cause normal current to flow. Care should be taken to use large cable for short-circuiting and to have good contacts.

Heating is determined by putting a normal load or overload on the transformer and observing the temperatures. Resistance measurements are taken on the coils to determine the rise by resistance and thermometer readings on the various parts of the transformer are made. Room temperature is carefully observed, as temperature guarantees are given in degrees rise above room temperature in case of oil-cooled and air blast transformers; in case of the water-cooled type the temperature of the ingoing water is taken, as rise is figured in degrees above the temperature of the cooling water.

In order to economize power, transformers are usually bucked, or arranged in a motor generator connection, for the heat run: only enough power is then required to supply the iron and copper losses. A diagram of two transformers so arranged is given in figure 1, and of three transformers in figure 2.

With the connection as shown in figure 1, except that a small fuse replaces the transformer used to supply current, a parallel run may be taken. This test shows whether polarity

and ratio are the same on both transformers. When voltage is put on the secondaries, and the fuse wire, connected to the primary of one transformer, is tapped on the primary terminal of the other, no spark will appear if ratio and polarity are

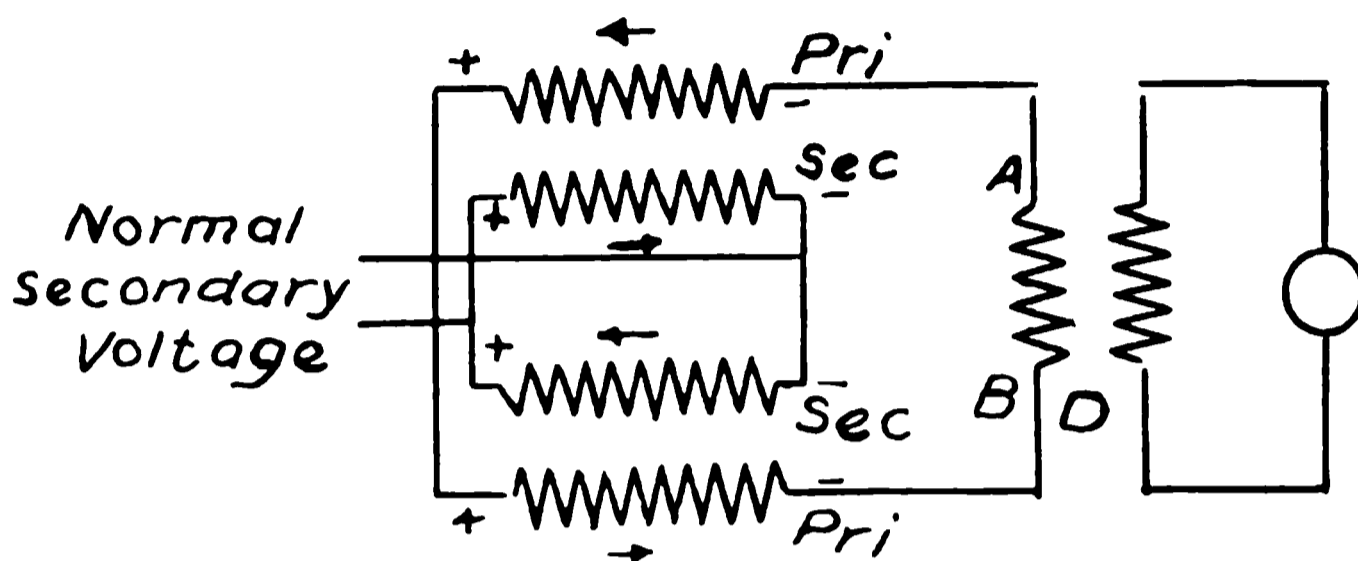


Fig. 1.

correct. If a spark does appear, read the voltage. If this is more than $\frac{1}{4}$ per cent of rated voltage, with full voltage on the secondary, the defect should be remedied before further test.

In these connections one alternator is used to furnish normal

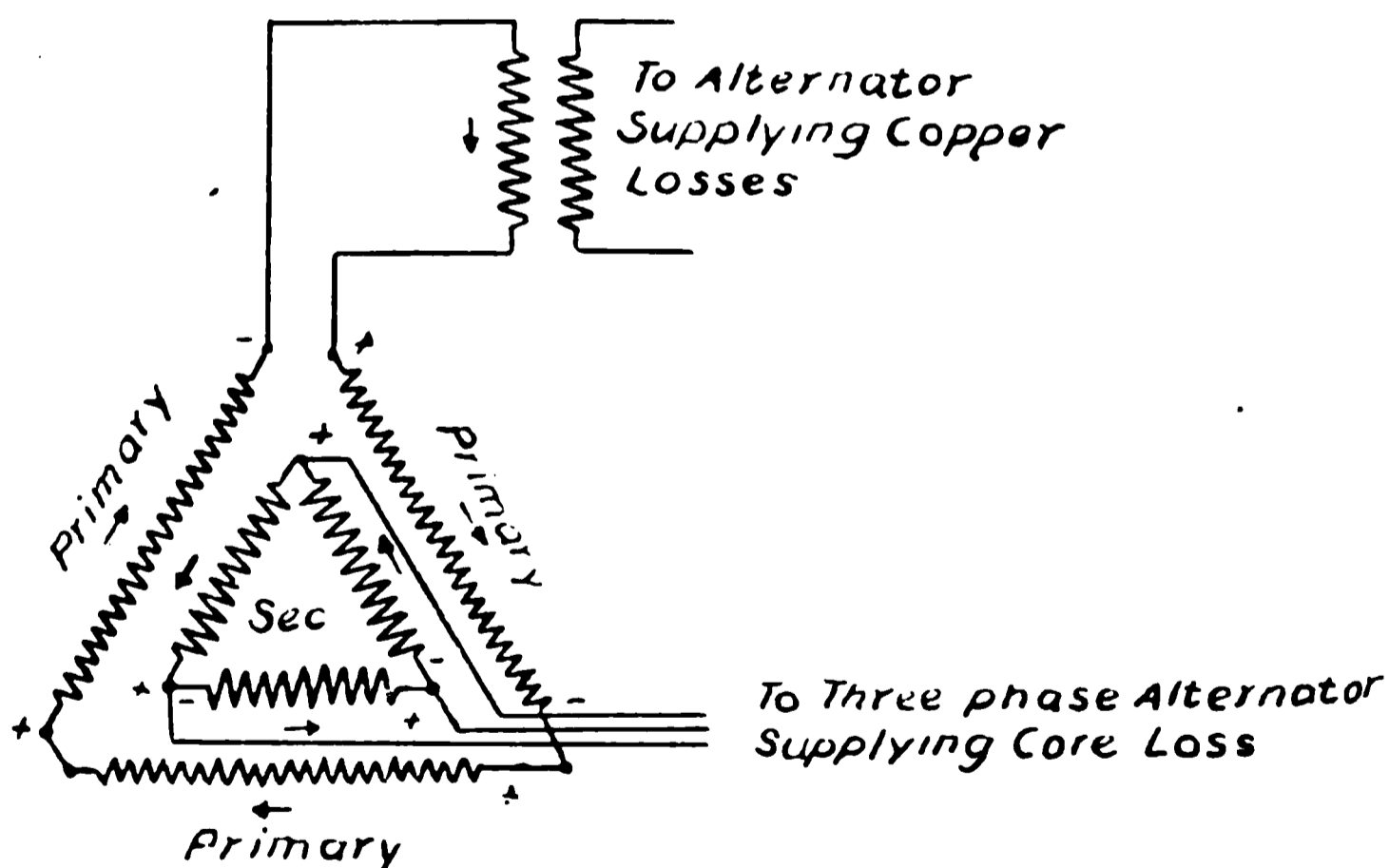


Fig. 2.

voltage, and the current is equal to the sum of the exciting currents of both transformers if they are connected as in figure 1, and to $\frac{1}{3}$ times the exciting current of one trans-

former if connected as in figure 2. The alternator supplying the copper losses will furnish normal current to the primaries and the voltage necessary to force this current through the windings is equal to the sum of the impedance volts of the transformers.

There should always be a transformer between the primaries of the transformers in test and the alternator, and care should be taken not to overload either this transformer or the alternators. The alternator should work at about normal excitation and if necessary the excitation current should be stepped up or down. During the heat run, and, in fact, whenever voltage is on the transformers, care should be taken to see that neither the testers nor men working about the shop come in contact with the live parts. Probably the most effective safeguard is to put the transformers inside a fence, and wire the field of the alternator supplying voltage so that opening the gate will open the field. In this way if the ammeter is put on a box or ladder inside the fence, there will be no high voltage on the testing table.

In order to shorten heat runs, air blast transformers may be run for a few minutes without air, and water-cooled transformers without water, care being taken to see that they do not get too hot. Air blast transformers are generally guaranteed in degrees rise at a certain pressure, and this pressure may be maintained by varying the speed of the blower or giving part of the air another outlet. Water-cooled transformers are guaranteed in degrees rise above a certain temperature of incoming cooling water and this temperature is maintained by use of steam, if necessary, to heat the cooling water. The number of gallons of water per minute per transformer is also specified, and this must be measured, generally by an iron pot with a standard orifice.

Double potential for one minute should be put on the transformer after the heat run; it is necessary to use a high frequency machine for this test, owing to the saturation of the iron at normal frequency. After this test one and a half times potential should be applied for five minutes. High potential test is applied between the primary winding and the secondary and core, and at a lower potential between the secondary and core.

Readings on all these tests should be carefully recorded on

Regulation at the required load, generally full load, is obtained by the following formula:

$$\text{Primary IR} = \frac{\text{Pri. resistance} \times \text{Pri. current}}{\text{Pri. voltage}} \times 100 = \% \text{ drop.}$$

$$\text{Secondary IR} = \frac{\text{Sec. resistance} \times \text{Sec. current}}{\text{Sec. voltage}} \times 100 = \% \text{ drop.}$$

$$\text{Magnetizing I} = \sqrt{(\text{Exc. Current})^2 - \left(\frac{\text{Core loss watts}}{\text{Core loss volts}} \right)^2}$$

$$W = \frac{\text{Mag. I}}{\text{Rated amps.}} = \text{Wattless factor of current.}$$

$$\left. \begin{array}{l} \text{Reactive} \\ \text{drop, IX} \end{array} \right\} = \frac{\sqrt{(\text{Imp. volts})^2 - \left(\frac{\text{Imp. watts}}{\text{Imp. amps.}} \right)^2}}{\text{Rated volts}} \times 100 = \% \text{ drop}$$

For non-inductive load,

$$E = \sqrt{(100 + IR + WIX)^2 + IX^2}$$

For inductive load where P = power factor,

$$W = \sqrt{1 - P^2} + \frac{\text{Mag. I}}{\text{Rated amps.}}$$

$$E = \sqrt{(100 + PIR + WIX)^2 + (PIX - WIR)^2}$$

$$\text{Regulation} = E - 100.$$

If the foregoing computations show the transformer to be satisfactory and if the high potential tests show the insulation to be sufficient, it may be passed for shipment, so far as its electrical characteristics are concerned.

THE BUILDING OF A POLE LINE.

BY L. E. HURTZ, 'O3, GENERAL MANAGER LINCOLN (NEB.)
TELEPHONE CO.

This subject is a very large one and must be divided into classes according to the work to be performed. This paper will be devoted to some of the phases of telephone pole line construction although all pole lines have much in common.

A considerable amount of engineering work should be done before the promoting and financing of any proposition and we will assume that that part of the work is completed and will start in with the work of the engineer at the actual construction of the line.

The first work for the engineer will be to make a complete survey of the territory covered which shall include the location and classification of the probable subscribers marking the number in each block plainly on the face of the map. Then judging from the previous growth of the city, the character of its inhabitants, and a large number of other conditions, an estimate of the probable growth of each block or district should be made, marking on the face of the map the probable number of subscribers in five, ten or twenty years, showing the probable number that will use individual and party-line instruments. On account of the numerous improvements, inventions, and other developments being made in the telephone field it is probable that figuring ten years in advance would be as far as would be conservative at this time. When the final estimate has been made for each block or district there should be a grouping of districts, and at the center of each group should be shown the number of lines both present and future that will have to be carried into the office from that point.

It will next be necessary to choose the most available routes to the exchange for underground and aerial construction. These important lines should be located carefully with respect to probable future requirements, choosing streets from which present as well as future lines can be distributed economically, considering the topography of the ground and the most direct routes. Notes

should be made showing the location and size of trees and other pole lines or obstructions and, through the underground district, the location of sewers, water and gas mains, heating pipes and other subways.

After estimates for the present and ultimate distribution for each district have been made, the size of cables and the best method of carrying them to the central office must be considered and these calculations will help to determine whether there shall be one or more exchanges. Both of these questions depend to some extent upon the type of apparatus to be used. In very large cities the telephone systems usually consist of a number of exchanges of from five to fifteen thousand telephones each, located at suitable centers of distribution and connected together by trunking cables. This is true either of manual or automatic apparatus. There has recently been introduced a system of small branch exchanges to be used in connection with automatic equipment by the use of which it is found that a great deal of expense can be saved in the installation and maintenance of the cable plant and in many instances branch exchanges as small as one hundred subscribers are used.

Such small branches are not practical in manual exchanges and have been made so in automatic exchanges only recently by the manufacture of switching units which are self-contained and can be supervised by the central office attendant although they may be located several miles from the office. This plan makes constant attention unnecessary and thereby reduces the cost of operation to a point so low that the disadvantages of being isolated are offset.

We will not attempt to discuss the selection of apparatus, but will assume that it has already been chosen. The engineer now has a basis to work on, and can formulate several arbitrary plans of distribution. For instance, the cable can be carried direct from centers of distribution to the central office with all or part underground, using only one exchange. Or the city can be divided into districts as indicated by the survey, and several branch exchanges can be located with the estimated number and size of trunks between them. By figuring the original cost of operating, including interest and depreciation, the estimates for the various plans may be compared, and the one showing the lowest annual cost, provided it will give satisfactory service, should be chosen. The estimate chosen should be refined to meet

the requirements of the case more accurately; or if two estimates figure out close together, they should both be refined and figured very carefully before choosing between the two systems.

Now assume that the system has been chosen and laid out on the map. We then come to the actual building of the plant, and we turn our attention to the erection of the pole lines and cables in the aerial part of the system.

In this discussion we will not enter into underground construction and will assume that the plant will be a modern one using all cable distribution.

The poles in most common use are white cedar and chestnut, although many other woods have been used; but the above have given very satisfactory service. Poles made of reinforced concrete are being used to a limited extent and those companies using them recommended them very highly. In the central west the white cedar is used almost exclusively although some chestnuts have been tried and some western red cedars. The latter are famous for being very straight and sound, but they are usually very slim and are not much larger at the bottom than at the top. The western red cedar poles make a very stately looking line, but when obtainable the white cedar with its larger bottom is usually preferred. Northern white cedar poles are usually sold under the Northwestern Cedarmen's Association specifications, although most of the large buyers draw specifications somewhat more strict than those of the Cedarmen's Association.

Before setting, the poles should be shaved and carefully framed. That is, the top should be "roofed" by sawing off pieces at an angle of 45° to the side, leaving the top of the pole sharpened to an angle of 90° . A "roofed" pole sheds the water more effectively than if left flat, thus making the top less liable to decay. Gains or flat spots about one half inch deep should be cut in the poles that are to carry cross arms at the points where the arms are to be fastened, thus forming a good bearing for them, and one hole large enough to take a 5-8 inch through bolt should be bored through the poles at each gain that is to be used at once. The roofs and gains should be painted with a good paint that will close all the pores and thus stop the entrance of water and prevent decay. The butt should then be treated with some preservative. The one used most is a substance called carbolinum which has proven to be very valuable and in some cases actually doubled the life of the timber used. Since the labor of

replacing poles is so high, it is very essential that the poles last as long as possible without having to be reset or replaced.

The poles should be set substantially, and to make a good job, the soil and weather conditions should be taken into account. In ordinary soil not subject to floods, a good rule to follow is to set a 25-ft. pole 5 feet deep, and to dig the hole 6 inches deeper for each additional 5 feet of length. Thus a 40-ft. pole would be set $6\frac{1}{2}$ ft. deep which is probably a trifle deeper than they are usually set. If the ground is moist or marshy or if otherwise unsatisfactory conditions are met, special settings must be provided. For instance a barrel of sand is sometimes used at the bottom of the pole; or rocks, ties or timber are put in the bottom of the hole or a foundation of several inches of concrete is used or the pole is set entirely in concrete. Sometimes in street railway work, the butt is set in concrete to the depth of about six inches, then dirt filled in and tamped to within six inches or a foot from the top, then this part filled in with concrete, so that the strain of the span wire will be taken up in the enlarged surface at the top and bottom of the pole, at which points the strain is the heaviest.

Great care should be exercised in the location of poles. In the building of a new plant as well as in construction work in an old one, the law regarding the location of poles should be referred to, in order that it will not be necessary at some later time to move the poles, which is an expensive operation. Poles located in streets and alleys should usually be set on lot lines in order that the residents of the neighborhood cannot complain that they interfere with driveways, barns, etc. In setting poles along streets and alleys which are not paved, great care should be taken in their location, so that if paving is put down at a later time that it will not be necessary to move them. Here it might be stated that where two cables cross at right angles at intersections of streets, or of a street and alley, it is not good practice to locate a pole at the point where the intersection of the lines will be, for the reason that it runs a double chance of having to be moved if either street or alley is paved.

A very effectual way to overcome this trouble is by making what is known as an aerial turn as illustrated in figure 1, setting the four nearest poles back at such a distance from the intersection that there is little probability of their having to be moved. In case they should have to be moved at a later date, it

could be accomplished much easier than if the messenger and cable had been fastened to a pole at the corner.

Fir cross arms have been used most generally, and have given very satisfactory service when not painted. It seems that filling the pores with paint causes the arms to rot inside, with the consequence that some day they break off while they are apparently in good order. This is a source of accidents to employees on account of the arms not showing their real condition.

Locust pins have given most general satisfaction for many years. Many other woods have been used, among them being

Fig 1

oak, which is not satisfactory, and osage orange, which is very good. Iron pins are used by the telegraph companies but have not come in general use on telephone lines.

The hardware used should be heavily galvanized to secure long and efficient service. This is especially true in damp climates. While galvanized hardware lasts much longer than plain, it is open to the objection that all the threaded parts must be cut first and galvanized afterwards. This necessitates the cutting of

loose threads and making up the difference with a coat of spelter, which may come off later and leave a poor thread.

Anchors are very important. They should be used at every place where a branch leaves the main line or where there is an offset in the line and at every dead end. The material used for the "slugs" or dead men may be any one of several kinds. Those used most are wood, either logs, parts of poles, ties or other timber; these may be used plain or soaked in some preservative; treatment similar to that given pole butts. Since any of these wooden slugs will last but a comparatively short time under ordinary conditions, several patent metallic anchors have been put on the market in the last few years in an effort to get a cheaper and more durable anchor. Some of them are really meritorious and others have proven dismal failures, while almost any of them are of some service under the right conditions.

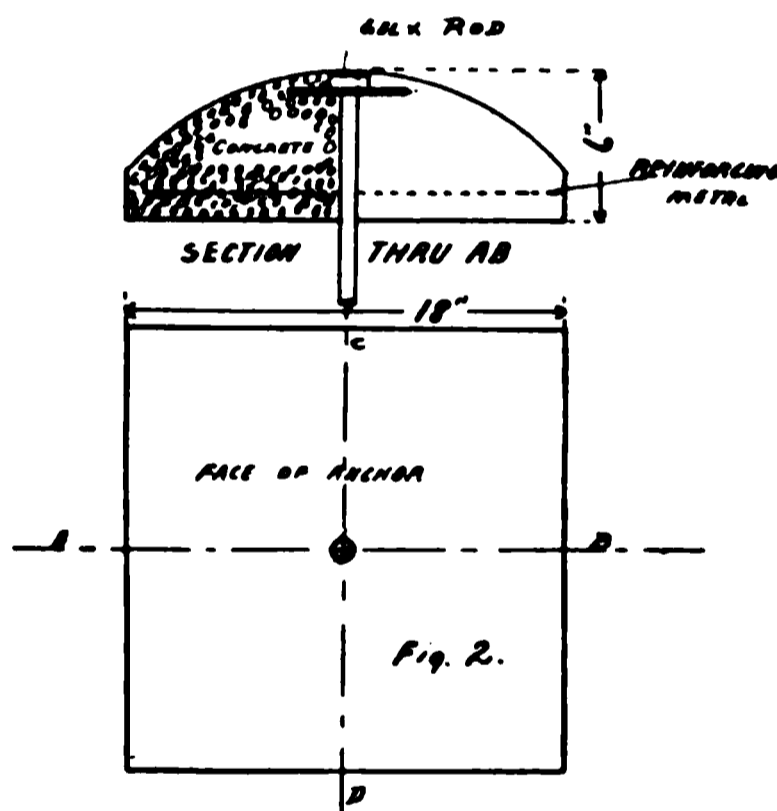


Fig. 2.

Considerable judgment must be displayed in choosing an anchor. Be sure that the size used is the smallest that will hold the load safely; but do not carry economy too far and get an anchor too small for the service required. By figuring the cost of material and labor of setting, it is an easy matter to choose the anchor giving the best result.

A new departure in anchors is the use of a reinforced concrete slab for the deadman, the idea being that the concrete slab is practically indestructable so that if the proper size is chosen it should last for a very long time without having to be replaced.

Concrete anchors have been used by the writer to hold me-

dium loads at the end of messengers carrying cables of various sizes. The dimensions of the anchors used most were as shown in figure 2. The face was 18"x18" square; the reinforcing metal being heavy steel, woven wire fencing, laid double about one inch from the face of the anchor; then about 4 to 6 inches of concrete was put behind the steel and the rod was put through the center of the slug.

While the material cost is slightly higher, the advantages of the concrete anchor are considerable. It can have a square face thus making it possible to use smaller holes than if a "slug" or tie had been used. Less tamping is required, because when the digging of the hole is nearly finished the bottom can be shaped into a mould, into which the concrete is poured; when hard, the anchor pulls squarely against a smooth surface of solid earth which is cut to the proper angle, so that all the tamping required is that necessary to keep the walls from caving in. When ordinary anchors are used the tamped loose dirt has to carry a part of the load.

The comparative cost of anchors is shown in the following table:

| | Concrete Anchor. | ½ of Oak Tie. |
|------------------------------|---------------------|------------------|
| Digging hole | \$0.45 | \$0.60 |
| Labor, making, tamping | .58 | .60 |
| Setting and material | .48 | .35 |
| Rod | .27 | .27 |
| | <hr/> | <hr/> |
| | \$1.78 | \$1.82 |

It shows that the concrete anchors were made at a slightly lower cost than the old style and they certainly ought to last much longer.

When an anchor has to hold an unusually heavy strain, the area of the slug or deadman is often increased by "planking," that is putting planks or timber in the hole in such a way that the anchor pulls against them, which serves to increase the anchor area to as great an extent as is desired. Anchors should be set as far back from the butt of the pole as the pole sticks out of the ground, that is, so that the guy wire pulls against the lead at an angle of about 45°. An anchor set within a few feet of the butt of the pole can hold but a very light load.

When locating an anchor, be sure that the anchor rod or guy

wire will not interfere with anyone's driveway or barn door or with any other private property; a little care may avoid having to reset the anchor at a later date.

Side and head guys should be used at intervals on all long heavy lines, in order that if the line is struck by a heavy storm or part of it wrecked by a fire or other trouble, the entire line will not be bowled over like a lot of tenpins.

The wire or cable used to connect the anchor to the line should be heavy enough to allow a reasonable margin of safety, and also should be double galvanized in order to insure it against rust for as long a time as possible. The materials usually used for messenger and guy wires are, (1) very hard and strong steel, which is very difficult to work with; (2) soft iron strand, which is very easy to work with but is too soft to give good results; and (3) Siemens-Martin steel strand, which combines great strength with pliability and ease of working. Any of the materials should be double galvanized.

All messenger wires should be left slack enough so that they are not stretched to their elastic limits, which amounts can be determined for the various sized messengers from manufacturers' tables. But most practical foremen do not use a dynamometer, and judge the tightness by the sag between spans. At the points where messengers and guys dead end the poles should be protected by shims or pieces of metal so put on that the wires cannot cut into the poles.

The messenger should be supported by a hanger which will hold it firmly and permanently; the hanger should be fastened to the pole by a through bolt. The use of lag screws should be avoided.

The cable most generally used consists of soft drawn copper conductors of 19, 20, or 22 B & S gage, insulated with one or two layers of dry paper; one of the wires of each pair is usually wrapped with a colored paper to distinguish between them. The wires are then twisted together, one turn every three inches, then several pairs are twisted together; then another layer of pairs are twisted on the core in the opposite direction; and thus built up in alternate layers to the desired size; the core thus formed is wrapped with heavy paper and covered with an airtight lead sheath. The size of the conductor, the amount of insulation, the composition and size of the sheath and other specifications vary for the several uses to which the cable is to be put.

One very important specification is the electrostatic capacity, which is varied by the distance between the wires and their insulation. Thus a change in the E. S. C. varies the price of the cable by changing the size of the lead sheath. In ordinary plants, Number 22 gage cable with an electrostatic capacity of from .09 to .12 microfarad per mile, is used, the insulation being one or two layers of dry paper and the sheath of pure lead, the thickness of which varies according to the size of the cable. For trunk cables larger conductors are ordinarily used, with lower capacity and heavier sheaths; and for underground work the lead sheath usually contains 3% of tin to harden it.

Cable hangers of various types are in use, the most popular being loops of Marlin or Houselene twine hung on hooks of



Cable Crossing Showing "Aerial Splice."

galvanized iron. Some companies use hangers which are made of metal. The weight and specifications of hangers depend on the size of cable to be carried.

The splicing of the cable is of great importance. The insulation of the wires must be removed, the wires twisted together and insulated with paper sleeves; care being exercised to splice white to white and red to red, etc., to keep the colors straight throughout the length of the cable. The joint when the splicing is finished should be thoroughly freed from moisture by pouring boiling paraffine over the wires, taking care that the temperature of the paraffine is high enough to boil out the moisture and not

hot enough to char the insulation. The finished splice must be enclosed in an airtight cover; the best job is done by using a lead sleeve similar to the sheath, and wiping the joints with solder.

There are several types of patent joints designed to enable anyone to splice and repair cable. These usually depend on gasket joints to prevent the entrance of moisture, and ordinarily are not to be recommended; except possibly for small plants which cannot afford a regular splicer and have no way to get one on short notice.

Example of Unprotected Terminal

Splices must be made in all positions, vertical and horizontal, and may join the ends of one or more cables in one splice. When the poles are properly set so that in alleys or streets at crossings there are no poles, "aerial splices" are made at the crossing points of the messengers, which are substantially clamped or wired together. An aerial splice is shown on page 101. The two ends of the cable spliced into the main cable are lashed strongly

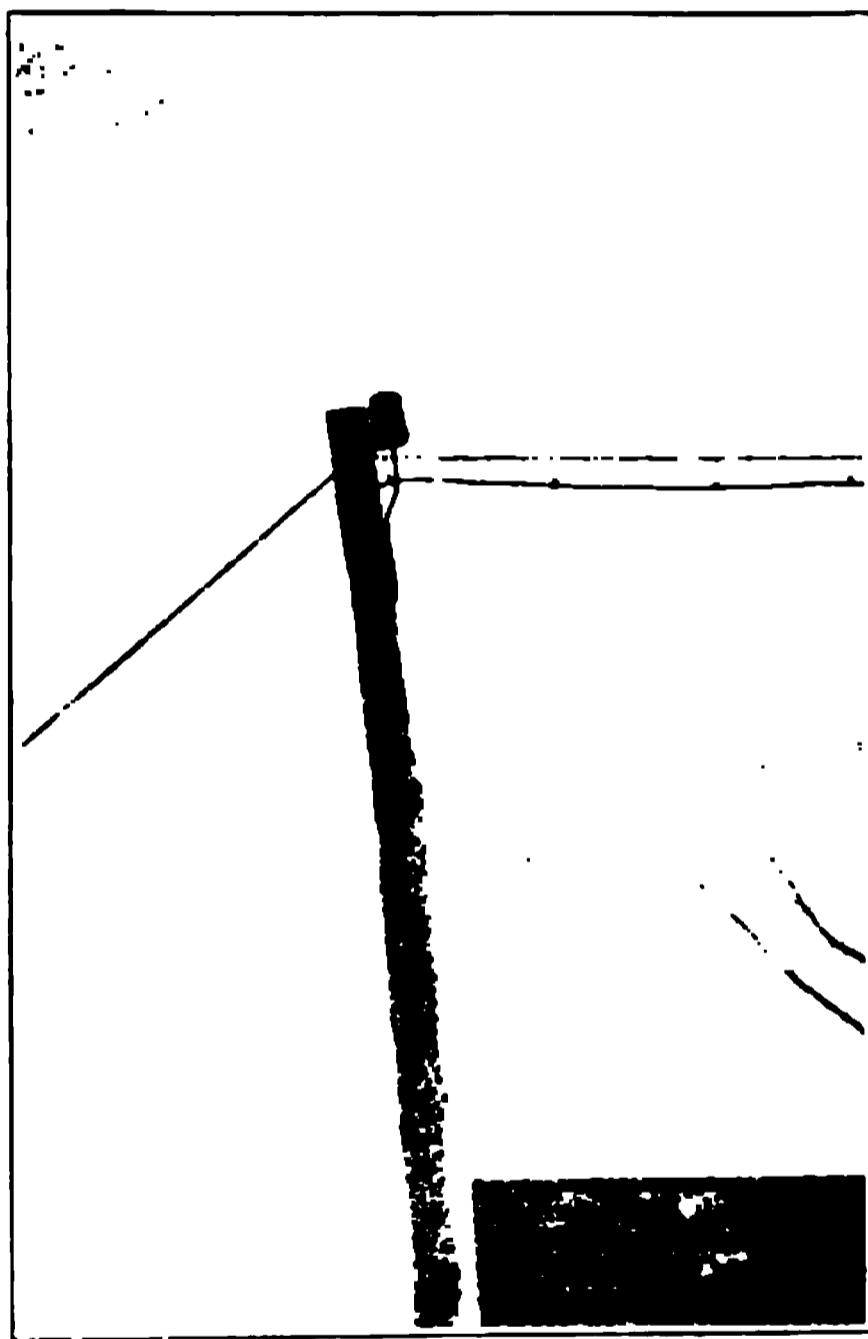
to the main cable with Marlin twine which prevents damage to the splice from strains on either side.

The wires in the cable must be brought out at various places in order to connect subscribers to the exchange. For this cable terminals or "cans" are used. They are of many different types, the principal types being protected and unprotected. Both types have their champions among the large operating companies, so that the choice is about evenly divided.

Protected Terminal at End of Cable, Showing "Drop" Wires Running From Pole to Subscribers' Houses.

In one type of unprotected terminal the paper insulated wires run directly into the terminals, and the wires are soldered to binding posts which extend through the walls of the central chamber; this chamber is then filled with a waterproof compound to keep out moisture. Other types of unprotected terminals are made without the central chamber, and in order to keep moisture out of the cable it is necessary to splice rubber insulated

cable on the end of the paper insulated cable. The protected terminal is connected to the cable in a manner similar to the unprotected, but at the binding posts there is furnished a lightning arrester, composed of two blocks of carbon separated by a mica strip; one block is grounded and the other attached to the line; to the line carbon is connected a fuse, and to this the terminal to which the drop wire is connected. The drop or service wire is then run, usually of twisted rubber-insulated wire, from the drop terminals to the house.



Protected Terminal at End of Cable

The difference in terminals can be summed up as follows: Protected terminals offer good lightning and fuse protection to the cable, thus insuring it against trouble from ordinary lightning or foreign currents, but introducing the objection of making occasional inspections necessary to clean the carbons and replace fuses; the first cost is higher.

The unprotected terminals are simpler, cheaper, and require

less attention; but when lightning strikes the line or a high potential wire crosses with the line, the lack of protection usually allows a large amount of damage to be done to the cable and sometimes to the entire equipment of the plant, a part of which might have been saved by using protected terminals.

When the company is not willing to have the cable entirely unprotected, and desires to reduce the construction cost, cheaper protected terminals, using rubber covered cable or potheads, may

Protected Terminal as Used in Combination Distribution

be obtained; but on account of the comparatively short life of the rubber insulation, it has been found desirable by some companies to combine the types. For instance, at the point where a cable is to branch out to serve a neighborhood, the cable is run into a protected terminal and out again from the line contacts, then carried on and distributed as originally intended, using unprotected terminals. Thus for example in a certain multiple distribution, one 25-pair protected terminal and perhaps five 10-

pair unprotected terminals will be used, which protects the main cable and reduces the cost materially.

Another method of reducing the cost and securing first-class protection is by using the so-called unit type protector. This consists of an ordinary terminal with the protection mounted separately, so that only the frame is put up at first; the protection is added from time to time, as needed.

To get a number of lines into large buildings and properly distribute them on the various floors, it is customary to use cables throughout the buildings, entering either aerial or underground; then running a cable to each floor, terminating in special boxes made for that purpose. This kind of construction is a trifle more expensive at first, but is very much the cheaper form in the long run.

The item of labor is such a large percentage of the cost of the line, and is ordinarily so hard to get at accurately, that figures have been appended showing average costs for the labor on certain parts of building a modern all-cable telephone plant in a suburb of a city, the population of the suburb being 3,000. These figures are as accurate as they could be kept by a good construction foreman who as usual was not a good bookkeeper, but the addition of a reasonable percentage for errors will give an idea of the cost for this part of the work.

| | Cost Each |
|--|-----------|
| Poles unloaded, 363 | \$0.07 |
| Poles shaved (average, 30 feet long) | .22 |
| Poles roofed (and a very few gains cut) | .07½ |
| Poles hauled (average, 30 feet long) | .25 |
| Poles set (average, 30 feet long) | .33 |
| Poles set (average 40 feet long) | .60 |
| Poles bored for steps | .18 |
| Poles stepped | .20 |
| Pole holes dug, average 30 feet, pole holes 5 1-2 feet deep | .47½ |
| Anchors, holes dug, 99 | .45 |
| Anchors set, 99 | .58 |
| X-arms fitted | .07 |
| X-arms distributed | .09 |
| X-arms put on | .15½ |
| Guys put on | 1.00 |
| Stringing and pulling messenger, per foot | .00½ |

| | |
|---|----------------------|
| Cable pulled, average 25 pr., per foot..... | \$0.00 $\frac{3}{4}$ |
| Cable clipped (hangers put on), per hanger..... | .00 $\frac{1}{3}$ |
| Staking out line, per pole | .10 |
| Poles pulled and holes filled, per pole..... | .65 |
| Cable unloaded, average 25 pr. per foot..... | .00 $\frac{1}{3}$ |
| Drops strung, per drop..... | 1.04 |
| Bare wire strung, per single wire per mile..... | 2.75 |

Average total cost of labor and material for splicing lead covered, paper insulated, telephone cable:

| | |
|---------------------|--------|
| 25 pr. cable | \$2.86 |
| 50 pr. cable | 2.95 |
| 75 pr. cable | 4.40 |
| 100 pr. cable | 5.75 |
| 150 pr. cable | 6.22 |
| 200 pr. cable | 8.37 |
| 250 pr. cable | 10.00 |
| 300 pr. cable | 10.00 |

In general a line should be substantially built of the best material obtainable for the purpose, and be constructed as nearly like the "One Horse Shay" as possible. In a well built line, certain parts will not have to be replaced from time to time, but the entire line will be serviceable without any rebuilding until all its parts are worn out.

ENGINEERING SOCIETY NOTES.

WHAT THE SOCIETY IS DOING.

The Engineering Society was organized November 27, 1900, its object being to promote interest in engineering at the University of Nebraska, to bring the students of the various engineering departments into closer fellowship, and to obtain engineers of prominence and experience to address the engineering students at various times.

The present year has been very prosperous in the way of increased membership. There was a student and alumni membership of 250 at the beginning of the year which has been increased by 65 members up to date, March 1, 1908, making an active membership at present of 125.

Five honorary members have also been elected. Mr. V. L. Hollister, Instructor in E. E., Prof. P. K. Slaymaker of the Applied Mechanics Department, and Mr. J. E. Rasmussen of the same department; Alfred Boyd, Instructor in C. E.; Albert Bunting, Instructor in M. E.

At the first meeting of the year the following officers were elected:

| | |
|------------------------------|-----------------------|
| President..... | John C. Page. |
| Vice-President..... | R. E. Guthrie. |
| Recording Secretary..... | W. S. Houseworth, Jr. |
| Treasurer..... | E. L. Turner. |
| Corresponding Secretary..... | E. F. Guidinger. |

A smoker was given in the early part of the year for the engineering students which was well attended by the under classmen and was considered as one of the most successful in the history of the society. Another smoker is being arranged, also a hop to be given April 3, in addition to the annual banquet to come later in the spring.

Since January, 1908, the society has had the use of quarters in the new University Temple for holding its meetings. It is a large, nicely furnished room, well lighted, and is a much more cheerful and commodious meeting place than the class rooms have been in the past.

A number of addresses have been given before the society this year. Dean C. R. Richards gave a talk upon "Our New Engineering Building," which was very interesting from an

engineering standpoint as well as otherwise, since we were at last assured by the exhibition of the plans and drawings that the erection of the new engineering building was a certainty.

It is a much needed building on Nebraska campus and it is with pleasure that we look forward to the future of the engineering student in his new home at Nebraska University. It is to be an example of modern practice in constructions of this nature. Dean Richards made a tour of inspection of engineering schools of the east and south during the summer of 1907, and has combined in the design and arrangements of this new building all the best features observed upon this tour, and at the same time avoided all the practices which were found to be unsatisfactory. Work will begin on the building this spring and it will be ready for occupancy in 1909-10. With this new building and equipment, Nebraska University should be placed near the head of western schools for the study of engineering.

The other addresses that have been made were as follows: Prof. P. K. Slaymaker, upon "The Manufacture of Pig Iron"; Mr. V. L. Hollister, upon "Static Electricity and Lighting Effects"; F. T. Darrow, Prin. Ass't Civil Eng. of the C., B. & Q. R. R., upon "Inspections and Inspectors"; B. C. Adams, Gen'l Supt. of the Lincoln Gas Co., upon "Lincoln Gas."

Other addresses are being arranged for by the program committee to be given later in the spring.

It is of interest to note that a movement is on foot among the electrical students to organize a Nebraska University Branch of the American Institute of Electrical Engineers.

ALUMNI DIRECTORY.

This directory contains the names of all the graduates of Engineering Courses from the University, also a few graduates of other courses who have taken up engineering work, and a few who left school before graduation and are engaged in engineering work. The addresses have been corrected to the best of our knowledge to date, March, 1908. The editors will be pleased to receive any corrections or additions to be filed for the use of their successors.

- Abel, G. P., B. Sc., C. E., '06. Lincoln, Neb., Eng. Dept. C., B. & Q. R. R.
Akerlund, F. R., B. Sc., M. E., '06. Valley, Neb.
Albers, Juergen, B. Sc., C. E., '93.
Anderson, C. E., B. Sc., E. E., '98. Craig, Neb.
Anderson, E. E., B. Sc., C. E., '05. Lincoln, Neb., Ass't Supt. of Construction, U. of N.
Andrew, J. W., M. E. Mgr. Tool & Railway Specialty Mfg. Co., 1434 Kansas Ave., Atchison, Kan.
Arnold, Bion J., E. E., '98. 181 La Salle St., Chicago, Ill., Pres. of The Arnold Co.
Bailey, B. P., '93. Okmulgee, Okla., Electrician.
Baker, L. N., B. Sc., M. E., '07. Beatrice, Neb.
Barks, F. S., '02. Omaha, Neb., M. E. Dept. U. P. R. R.
Barkley, J. A., B. Sc., E. E., '92. Gen'l Mgr. Port Elizabeth Tramway, Port Elizabeth, Cape Colony, So. Africa.
Bates, G. W., B. Sc., C. E., '05. 327 No. 31st St., Lincoln, Neb., Asst. State Engineer.
Battan, Roy, B. Sc., C. E., '07. 308-9 Columbia Blk., Spokane, Wash., Draftsman with Washington Water Power Co.
Bay, Burt, B. Sc., E. E., '06. Westinghouse Sales Dept., 705 Land Title Bldg., Philadelphia, Pa.
Beardslee, C. O., Lincoln, Neb.
Bedell, C. E., B. Sc., E. E., '00. Pittsburg, Pa., Designing Eng. Westinghouse Mfg. Co.
Belden, C. E., B. Sc., E. E., '07. Dawson, Neb.
Belknap, L. J., B. Sc., E. E., '98. St. Louis, Mo., Sales Eng. Wagner Elec. Co.
Bell, J. H., Ocotlan, Jalisco, Mexico, R. R. Contractor.
Benedict, B. W., B. Sc., M. E., '01. Topeka, Kan., Staff of Asst. Supt. M. P. Santa Fe Ry.
Benjamin, W. E., B. Sc., C. E., '96. Cheyenne, Wyo., Deputy Co. Clerk.

- Bessey, E. A., B. Sc., E. E., '98. Great Barrington, Mass., Engineer in Instrument Dept. Gen. Elec. Co.
- Bessey, C. A., B. Sc., E. E., '99. Chicago, Ill., Sargeant and Lundie.
- Biggerstaff, C. D., C. E. 27½ So. 10th St., K. C., Kans., Architect and Draftsman K. E. C. S. Ry.
- Bixby, J. E., B. Sc., E. E., '01. 1516 Curtis St., Denver, Colo., Tele. Dept. Western Elec. Co.
- Bliss, E. F., B. Sc., E. E., '02. Schenectady, N. Y., General Elec. Co.
- Bolles, C. M., B. Sc., E. E., '06. Chicago, Ill., Western Elec. Co.
- Bowlby, H. L., B. Sc., C. E., '05. Seattle, Wash., Instructor in C. E. Uni. of Washington.
- Brackett, E. E., B. Sc., E. E., '01. Philadelphia, Pa., Instructor in E. E. University of Pennsylvania.
- Brigham, E. W., B. Sc., E. E., '06. Schenectady, N. Y., General Elec. Co.
- Brook, I. E., B. Sc., E. E. Chicago, Ill., The Arnold Co.
- Brooke, W. E., B. Sc., C. E., '92. Minneapolis, Minn., Uni. of Minn.
- Brooks, G. W., B. Sc., E. E., '02. Schenectady, N. Y., Construction Foreman, Gen. Elec. Co.
- Brown, A., B. Sc., '03. Aurora, Neb.
- Brown, G. F., B. Sc., '04. 785 State St., Schenectady, N. Y., A. C. Eng. Dept. G. E. Co.
- Brockway, P. L., B. Sc., C. E., '05. 803 So. Water St., Wichita, Kans., Civil Engineer.
- Bruce, J. A., B. Sc., '03. Eng. Dept. U. P. Ry.
- Bryan, C. H., Cedar, Colo. Chem. Eng.
- Buckley, N. E., B. Sc., '03. 914 So. 26th St., Omaha, Neb., Asst. Eng. U. P. Railroad.
- Buckstaff, F. B., B. Sc., '03. Chicago, Ill., Estimator, Henry Pratt Boiler & Machine Co.
- Burkey, C. R., B. Sc., C. E., '06. Boise, Idaho, Eng. Dept. U. P. R. R.
- Burr, F. D., B. Sc., E. E., '02. Hawserlake, Mont.
- Campbell, S. C., B. Sc., M. E., '02. Rockhill, S. C., Manufacturer of Ice.
- Carter, A. E., B. Sc., C. E., '99. C. E. Columbia Uni., 449 W. 123d St., N. Y. C., Res. Eng. Rapid Transit Subway Co.
- Case, M. B., C. E. Box 89, Vancouver, Wash., Asst. Eng. Vancouver Bridge.
- Charles, E. D. Wisner, Neb., City Electrician.
- Chase, L. W., B. Sc., M. E., '04. 1245 No. 33d St., Lincoln, Neb., Assoc. Prof. Farm Mech's, Uni. of Neb.
- Chessington, J. B., C. E. Thermopolis, Wyo., City Engineer.
- Christensen, W., '00. Utah, Mercur Mining Co.
- Clinton, S. D., B. Sc., C. E., '02. Irrigation Engineering, Idaho.
- Cole, C. L., B. Sc., M. E., '06. 3920 Lake Ave., Chicago, Allis-Chalmers Co., Milwaukee. Testing Dept.
- Collet, A. J., B. Sc., M. E., '00. Omaha, Neb., Chief Electrical Engineer, U. P. Ry.

- Cornell, C. B., B. Sc., E. E., '04.
- Cortelyou, S. V., B. Sc., C. E., '02. San Fernando, Pamp. P. I., District Engineer Fourth District.
- Costelloe, M. F. P., B. Sc., C. E., '06. Fort Morgan, Colo., Civil and Irrigation Engineering.
- Corr, Ray, B. Sc., M. E., '04. Indianapolis, Ind., Atlas Engine Works.
- Cramer, D. L. Dutchcreek, Nev., Mining Engineer.
- Crane, C. O., B. Sc., E. E. Chicago, Ill., Arnold Elec. Power Sta. Co.
- Crook, Z. E., B. Sc., E. E., '97. Faribault, Minn., Res. Eng. C. M. & St. P. R. R.
- Crownover, C. E., B. Sc., C. E., '97. 1502 Pacific Ave., Everett, Wash., Locating Eng. G. N. Ry.
- Currier, H. C. Omaha, Neb. Eng. Dept. Neb. Telephone Co.
- Cushman, C. R., B. Sc., E. E., '02. Lincoln, Neb., Cushman Motor Co.
- Cutshall, L. A., B. Sc., E. E., '05. El Paso, Texas, Southern Independent Telephone Co.
- Davis, C. L., B. Sc., E. E., '06. 811 Franklin Ave., Wilkinsburg Sta., Pittsburg, Pa., Westinghouse Mfg. Co.
- Davis, E. O., B. Sc., C. E. '05.
- Davis, T. B., B. Sc., M. E., '06. Wickliffe, Ohio.
- Davidson, J. B., B. Sc., M. E., '04. Ames, Iowa, Professor of Agricultural Engineering at Iowa State College.
- Debler, B. E., B. Sc., C. E., '07. Spokane, Wash.
- Day, W. F., B. Sc., C. E., '06. 1608 Franklin St., Denver, Colo., Asst. Eng., J. G. White Co.
- Dobson, Frank A. 220 No. 26th St., Lincoln, Neb., Contracting Eng.
- Dormann, F. B., B. Sc., M. E., '01. Denver, Colo., American Bridge Co.
- Doubrava, H. W., B. Sc., E. E., '97. 17 Battery Place, N. Y. C., Sales Eng. N. Y. Office Wagner Elec. Mfg. Co.
- Doubt, J. C., Jr., B. Sc., '03. 522 Broadway, Seattle, Wash., Kilbourne & Doubt, R. A., B. Sc., E. E., '01. New York City, Western Elec. Co. Clarke Co.
- Downes, N. W., B. Sc., M. E., '07. Omaha, Neb., Mechanical Eng. Dept. U. P. R. R.
- Duer, C. B., B. Sc., F. E., '07. Hastings, Neb.
- Dwyer, R. C., B. Sc., E. E., '07. 811 Franklin Ave. Wilkinsburg, Pa., Apprentice Dept. Westinghouse E. & M. Co.
- Dumont, R. E., B. Sc., C. E., '06. 3642 Lafayette Ave., Omaha, Neb., Asst. Eng. C. & N. W. Ry.
- Eagleson, E. G., B. Sc., C. E., '89. Boise, Idaho, U. S. Surveyor Gen'l for Idaho.
- Early, J. W., B. Sc., E. E., '07. Columbus, Neb., Consulting Engineer.
- Ellis, O. A., B. Sc., C. E., '07. Panama, Neb.
- Elmen, G. W. Schenectady, N. Y., Gen. Elec. Co.
- Elson, T. H., '03. Kearney, Neb.

- Elson, W. D. Cleveland, Ohio, Western Elec. Co.
- Engel, C. W., B. Sc., C. E., '03. 66 U. S. Nat'l Bank Bldg., Omaha, Neb.,
Asst. Eng. C. & N. W. Ry.
- Evans, H. T., B. Sc., E. E., '98, E. E., '01. Boulder, Colo., Prof. of E. E.
University of Colorado.
- Everett, C. C. Eureka, Utah, Supt. W. S. Mining Co.
- Fairman, F. F., B. Sc., E. E., '06. Chicago Ill., Western Elec. Co.
- Farnsworth, G. E., B. Sc., C. E., '04. Hooper, Wash., Draftsman North
Coast Ry.
- Fenlon, J. A., B. Sc., C. E., '07. David City, Neb.
- Forbes, B. E., A. B., '95. Fort Laramie, Wyo., Care of U. S. R. S., Eng.
U. S. Reclamation Service.
- Frazier, B. R., B. Sc., E. E., '07. 1011 Albany St., Schenectady, N. Y.,
Apprentice G. E. Co.
- Friedman, S., B. Sc., C. E., '06. Omaha, Neb., Collins Const. Co.
- Fritts, C. B., B. Sc., E. E., '96. Kansas City, Mo., Genl. Mgr. Metropolitan
St. Ry. Co.
- Gibbs, J. B., B. Sc., E. E., '05. 852 Rebecca Ave., Wilkinsburg, Pa., Eng.
Dept. Westinghouse E. & M. Co.
- Grant, Wm., B. Sc., C. E., '97. Lincoln, Neb., City Eng.
- Green, J. A., '04. Denver, Colo., J. G. White & Co.
- Green, Wm., '98. Kansas City, Mo., K. C. Telephone Co.
- Griggs, C. E., E. E., '97. Utah, Mining Engineer.
- Gutleben, D. B., '00. Cleveland, O., American Sugar Mach. Co.
- Hagenow, Chas., B. Sc., E. E., '00. Houghton, Mich., Mathematics In-
structor, Michigan School of Mines.
- Hagensick, E. H., B. Sc., E. E., '06. Omaha, Neb., Elec. Dept. U. P. Ry.
- Hall, D. C., B. Sc., E. E., '98. 261 Carlton Ave., Brooklyn, N. Y., Electri-
cal Inspector U. S. Navy.
- Hamilton, W. G., B. Sc., E. E., '06. 811 Franklin Ave., Wilkinsburg, Pa.,
Apprentice Westinghouse E. & M. Co.
- Harris, R. S., B. Sc., C. E., '04. 430 Paxton Blk., Omaha, Neb., Pres.
Western Contr.'s Sup. Co., and Standard Lbr. Co.
- Hartley, Harry K., B. Sc., E. E., '07. Anaheim, California.
- Hartsough, G. H., B. Sc., E. E., '07. 418 Biddle Ave., Wilkinsburg, Pa.,
Apprentice Westinghouse E. & M. Co.
- Harvey, A. L., B. Sc., E. E., '06. 755 Franklin Ave., Wilkinsburg, Pa.,
Westinghouse E. & M. Co.
- Hartzell Walter, B. Sc., E. E., '05. Pittsburg, Pa., Westinghouse E. &
M. Co.
- Hastie, A. G., B. Sc., E. E., '07. 839 Rebecca Ave., Wilkinsburg, Pa., Ap-
prentice Westinghouse E. & M. Co.
- Hawksworth, D. W., B. Sc., E. E., '97. Montreal, Canada. Asst. to Vice-
Pres. American Car & Foundry Co., Ltd.

- Haughton, E. H., B. Sc., E. E., '95. 315 Dearborn St., Chicago, Ill., Gen. Mgr. Bryan-Marsh Co.
- Heaton, R. H., B. Sc., M. E., Beloit, Wis., Fairbanks-Morse Gas Engine Works.
- Hedge, Verne, A. B., B. Sc., C. E., '03. Lincoln, Neb., Abstracter of Titles for Lancaster Co.
- Hedges, G. L., B. Sc., E. E., '07. Sta. A, Lincoln, Neb., Asst. Superintendent Grounds and Buildings, University of Nebraska.
- Heimrod, A. A., B. Sc., C. E., '06. Omaha, Neb.
- Henck, C. H. 311 Laurel St., Baton Rouge, La.
- Henry, J. E., B. Sc., C. E., '05. St. Joseph, Mo., Builder and Contractor.
- Hershey, J. L., B. Sc., C. E., '06. Lincoln, Neb.
- Hess, F. E., B. Sc., C. E., '03. Dallas, Texas, Hess & Skinner, Gen'l Agts. Missouri Valley Bridge & Iron Co.
- Hibner, A. E., B. Sc., E. E., '06. Lincoln, Neb.
- Hitchman, J. C., B. Sc., E. E., '98. Tampico, Mex., Mexican Central Ry.
- Hoagland, A. L., B. Sc., E. E., '00. Lincoln, Neb., Resident Engineer C. B. & Q. R. R.
- Holman, W. H., B. Sc., E. E., '04.
- Holmes, J. C., B. Sc., C. E., '05. Omaha, Neb.
- Horn, A. C. Blackfoot, Idaho, Foreman S. R. V. Co.
- Howe, E. D., B. Sc., C. E., '87. Table Rock, Neb., County Surveyor.
- Hubbard, Ray D., B. Sc., C. E., '00. Klamath Falls, Ore., Office Eng. U. S. R. S.
- Hulett, R. E., B. Sc., E. E., '99. Bay City, Mich., Elec. Eng. Hecla Portland Cement Co.
- Hull, A. M., B. Sc., E. E., '03. Fremont, Neb.
- Hummel, C. M., B. Sc., E. E., '00. 2333 Papin St., St. Louis, Mo., Sec.-Treas. O. K. Karry Steel Co.
- Huntington, L. M., B. Sc., C. E., '02. Santiago, Cuba, Asst. Engineer of Municipalities.
- Hurlburt, H. S. G., B. Sc., E. E., '05. Tonopah, Nevada, Tonopah Mining Co.
- Hurtz, L. E., B. Sc., E. E., '03. Lincoln, Neb., Gen'l Mgr., Lincoln Telephone Co.
- Hunt, F. L., B. Sc., E. E., '02. 84 State St. Boston, Mass., Asst. Eng. Boston Office, Gen'l Elec. Co.
- Hyde, M. A., B. Sc., E. E., '98. 2544 Vine St., Lincoln, Neb., Gen. Agt. Midwest Life Ins. Co.
- Jackson, J. B., B. Sc., E. E., '07. Chicago, Ill., Western Elec. Co.
- Jeffrey, E. O., B. Sc., E. E., '00. Los Angeles, Cal.
- Jenkins, W. G., B. Sc., C. E., '07. Manzanillo, Cuba, 1st Asst. to Chief Eng. Manzanillo, Boyamo, Carretera.
- Johnson, C. A., B. Sc., E. E., '06. 755 Franklin Ave., Wilkinsburg, Pa., Apprentice Westinghouse E. & M. Co.
- Jones, J. C., '96. Salt Lake City, Utah, Westinghouse E. & M. Co.

- Jones, I. B., B. Sc., C. E., '07. Morrill, Neb., Constr. Eng. Tri-State Land Co.
- Jorgensen, H. W., B. Sc., C. E., '97. Box 673 Bisbee, Ariz., Civil and Mining Engineer.
- Joy, G. A., B. Sc., E. E., '01. Chicago, Ill., Telephone Eng. Kellogg Switchboard & Supply Co.
- Kathan, C. S. Aitken, Minn., Hydraulic Engineer.
- Kendall, H. C., B. Sc., E. E., '02. Milwaukee, Wis., Allis-Chalmers Co.
- Kendall, Val. H., B. Sc., E. E., '07. Niles, Mich., Kawnur Mfg. Co.
- Kemmish, N. A., B. Sc., M. E., '04. Lincoln, Neb., Lincoln Traction Co.
- Kinton, W. G., B. Sc., E. E., '98. 68 E. 36th St., Chicago, Ill.
- Koch, A. W. F., B. Sc., C. E., '05. Room No. 14, Burlington Depot, Lincoln, Neb., Eng. Dept. C., B. & Q. R. R.
- Kollasch, W. M., '02. Monadnock Blk., Chicago, Ill., Supt. Leonard-Martin Const. Co.
- Korsmeyer, L., B. Sc., C. E., '00. Lincoln, Neb., Korsmeyer Plumbing Co.
- Krasny, Emil, B. Sc., E. E., '03. Humboldt, Neb.
- Kruse, A. N., B. Sc., E. E., '03. New York City, Western Elec. Co.
- Kryder, J. F., B. Sc., E. E., '07. 811 Franklin Ave., Wilkesburg, Pa., Apprentice Westinghouse E. & M. Co.
- Kuhns, J. H., '96. Prof. of C. E. in University of Japan.
- Kutton, W. G., '98. Chicago, Ill., Chicago Telephone Co.
- Langer, J. F., B. Sc., E. E., '00. New York City, Electrical Inspector New York Navy Yard.
- Larson, C. H., B. Sc., '02.
- Larson, Wm. Eng. Dept. U. P. Ry., Omaha, Neb.
- Lawler, J. C., '02. Colorado Springs, Colo., Chief E. E. Colorado Springs Electrical Co.
- Lewis, E. O., B. C. E., '84. Falls City, Neb., Traveling Salesman.
- Liebmann, Morris N., B. Sc., E. E., '00. 160-62 Duane St., N. Y. C., Mgr. Foote-Pierson Co.
- Little, Chas. N., A. B., '79, A. M., '84. Yale Ph. D., '85. 818 Elm St., Moscow, Idaho, Prof. C. E., Idaho State University.
- Lord, H. S., B. A., '93. Butte, Montana, Civil Eng.
- Lott, A. L., B. Sc., E. E., '07. 1007 N. 22d St. So. Omaha, Neb., Eng. Dept. O. & C. B. St. Ry. Co.
- Lyman, S. B., B. Sc., E. E., '97. Wellston, Ohio.
- Lyon, G. J., B. Sc., '99. Colorado Springs, Colo., Prof. C. E. in Colorado College.
- Mallat, O. R., B. Sc., E. E., '07. Lincoln, Neb., Lincoln Gas & Elec. Co.
- Marsh, E. M., B. Sc., E. E., '07. Wilkesburg, Pa., Apprentice Westinghouse E. & M. Co.
- Maghee, W. M., B. Sc., E. E., '92. Rawlins, Wyo., Electrician.
- Manley, F. A., B. C. E., '89. Superior, Wyo., Supt. Superior Coal Co.
- Mansfield, R. J., B. Sc., M. E., '04. Wisner, Neb.

- McReynolds, R. H., B. Sc., E. E., '04. Vermillion, S. D., Supt. of Bldgs., University of South Dakota.
- McDowell, C. C., B. Sc., E. E., '05. Schenectady, N. Y., General Elec. Co.
- McCroskey, J. W., B. Sc., '91. London, Eng., Mgr. of J. G. White Co., Contractors, 9 Cloak Lane, E. C., London, Eng.
- McGeachin, W. R., B. Sc., E. E., '03. Manila, P. I., Supt. of Manila Elec. Light Plant.
- McNamara, C. J., B. Sc., C. E., '06. Rock River, Wyo., U. P. R. R.
- McWilliams, C. C., B. Sc., E. E., '07. Chester, Neb.
- Meade, A. E., B. Sc., C. E., '06. Lincoln, Neb., Eng. Dept. C., B. & Q. R. R.
- Meyer, F. L., B. Sc., E. E., '97. Trenton, N. J., Ins. Wire Dept. Jno. A., Roebling's Sons Co.
- Meyer, C. L., B. Sc., M. E., '07. 210 So. 36th St., Omaha, Neb., Spec. Apprentice U. P. Shops.
- Mielenz, A. H., B. Sc., M. E., '07. Wahoo, Neb.
- Miller, A. A., B. Sc., E. E., '98. Seattle, Wash., Sales Eng. Westinghouse E. & M. Co.
- Miller, A. E., B. Sc., M. E., '06. Newton, Iowa.
- Miller, J. W., B. Sc., C. E., '05. Deadwood, S. D., Eng. Dept. C. & N. W. R. R.
- Mills, D., B. Sc., E. E., '05. Omaha, Neb., U. P. Ry.
- Mills, R. S., B. Sc., E. E., '07. 427 Center St., Wilkinsburg, Pa., Apprentice Westinghouse E. & M. Co.
- Morse, P. A., B. Sc., E. E., '99. 810 Spruce St., St. Louis, Mo., Sales Mgr. Western Electric Co.
- Moser, W. A., B. Sc., E. E., '07. 427 Center St., Wilkinsburg, Pa., Apprentice Westinghouse E. & M. Co.
- Mueller, R. S., B. Sc., E. E., '98. 212 Electric Bldg., Cleveland, O., Mgr. Cleveland Sales Dept. Kellogg S. & S. Co.
- Mundorf, Wm., B. Sc., C. E., '02. Omaha, Neb., Designer Paxton & Vierling Iron Works.
- Munn, O. N. Nebraska City, Neb., with A. M. Munn Co.
- Newton, B. A., B. Sc., C. E., '04. No. 14 Burlington Depot, Lincoln, Neb., Transitman C., B. & Q. R. R.
- Nilsson, H. O., B. Sc., C. E., '06. 1715 So. 10th St., Omaha, Neb., Chief Engr.'s Office U. P. R. R.
- Noyes, H. B., B. Sc., E. E., '98. Omaha, Neb., Chief Eng. Omaha & C. B. Ry. Co.
- Noyes, R. E., B. Sc., E. E., '04. 1778 Ansel Rd., Cleveland, Ohio, Instructor in E. E., Case School Applied Science.
- Oliver, R. H., B. Sc., E. E., '03. Chicago, Ill., Arnold Elec. Power Sta. Co.
- Orton, C. S., B. Sc., M. E., '02. Milwaukee, Wis., Erecting Eng. Allis-Chalmers Co.
- Palen, Archie, B. Sc., C. E., '07. Lincoln, Neb.

- Palmer, W. R., B. Sc., E. E., '06. Schenectady, N. Y., General Elec. Co.
- Pearson, C. A., '01. Lincoln, Neb., Instructor Forge Work, U. of N.
- Pepperburg, A. J., '02. New York City, Navy Yard.
- Pierce, E. H., B. Sc., E. E., 942 Warren Ave., Chicago, Ill., Western Electric Co.
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- Podlesak, Emil, B. Sc., E. E., '96. No. 30 King St., Morristown, N. J., Contracting Engineer.
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- Wilson, G. E., B. Sc., M. E., '06. 4114 10th Ave., N. E. Seattle, Wash., Prof. M. E. in Washington University.
- Wilson, A. R., B. Sc., C. E., '07. Box 596, Pueblo, Colo., Eng. Pueblo Bridge Co.
- Woodward, W. R., B. Sc., E. E., '07. 1259 Franklin ave., Wilkinsburg, Pa., Apprentice West. E. & M. Co.
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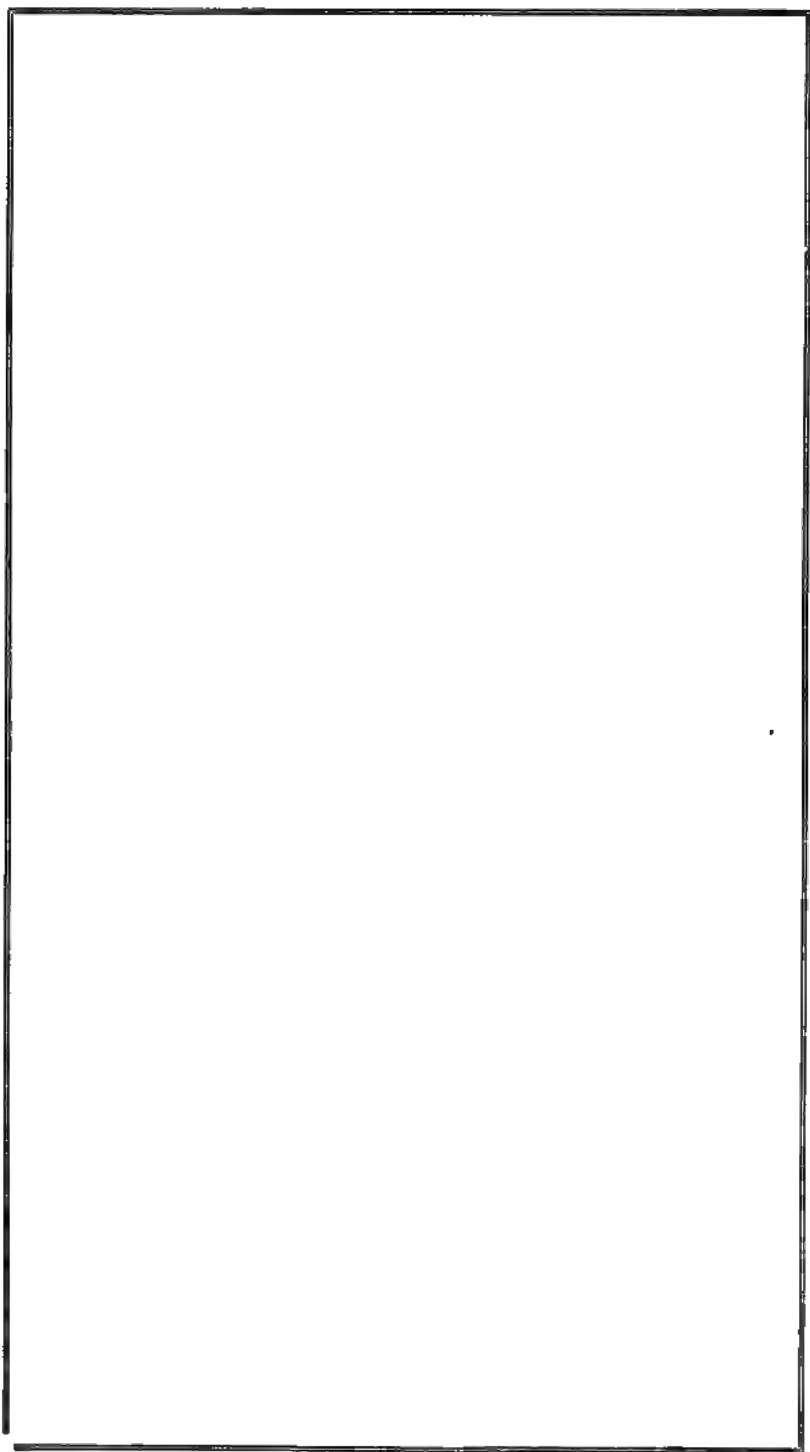
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FARE OF HIS STUDENTS AND HIS NINETEEN YEARS OF
CONTINUOUS EFFORT IN BUILDING UP THE CIVIL
ENGINEERING DEPARTMENT OF THE
UNIVERSITY OF NEBRASKA,
THIS VOLUME IS DEDICATED.

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ENGINEERING EDUCATION.

BY WILLIAM CLARENCE WEBSTER, PH. D.,
Professor of Commerce.

One of the most notable recent tendencies in higher educational institutions is the very large increase in the number of students taking engineering courses. A recent investigation shows that the number of engineering students in our colleges and universities increased 102 per cent during a four-year period, while the number of students in arts and science courses increased only 15 per cent during the same period. This tendency and the general drift of modern educational systems towards the utilitarian ideal is bemoaned by many arch-defenders of the old order, who can see in it nothing but a wanton sacrifice of culture and disciplinary training on the altar of selfish commercialism. The author of this short paper, for one, does not share this feeling. He sees in it rather a manifestation of a general tendency in education that started in the earliest civilizations, endured and grew stronger with each wave of development. From the earliest times to the present the prime object of every educational system has been to fit the student for the environment in which he was placed. All along the course of educational development one can see the prevailing educational

methods of different periods deeply influenced by fundamental social conditions and these social conditions in turn vitally affected by the prevailing educational methods. As far back as the historian can peer into the world's development he finds each civilization possessed of an educational system peculiar to itself: the Chinese had one system, the Hindoos another, the Greeks another, and the Romans still another; and each was admirably suited to the ends to be attained.

Coming down to modern times the careful student finds that every new type of education has been called forth by new social problems, and that new conditions have frequently altered the whole field of educational methods. The Renaissance unlocked for Europe the wealth of classical learning and fixed the study of Greek and Latin in school curricula. That may be considered the beginning of the so-called "classical courses" which have persisted to this day and continue, no doubt, to serve certain useful purposes for some students. The first radical revision of the old classical college course was caused by the development of natural science and its introduction as a systematic study into the college course. The organization of great states in western Europe in early modern times necessitated the study of history, political science, jurisprudence, economics and finance. Eventually also a home-grown culture in western Europe and America made possible the profitable study of modern languages and literatures. Then came still newer conditions, the result largely of industrial evolution, which conditions were destined to influence the functions and methods of the school quite as powerfully as any previous force. The growth of industry from the crude hand-working stage to the modern factory system led to the establishment of numerous technical schools for engineers, chemists, electricians and others, and the development of new methods for the realization of educational ideals. No one today doubts the advantage of technical schools; they are as strongly instructed and as liberally supported as the older professional schools for the study of law and medicine.

What we wish to emphasize in this very brief outline of the world's educational development is this. To a great extent the school has always been a faithful reflection of the civilization of every people and period. From first to last the prime object of every educational system has been to fit the student for his life environment. Indeed, if any educational system is to be

successful it must have this for its object. We see therefore that the modern utilitarian trend of education is really only a manifestation of a general tendency that has always prevailed and must necessarily prevail. If we are to criticize this tendency at present, we must criticize the environment upon which it is based; if the present direction of this tendency is to be changed, the environment must be changed. It is as idle to try to check this utilitarian tendency in education as to try to stop Niagara, and as undesirable. Technical schools and engineering courses have come to stay and are bound to increase in numbers, size and importance as the years go by.

It may not be amiss to call attention to a still more recent tendency in educational development, viz., the creation of schools and departments in many large universities for providing higher training for business. The recent marvelous evolution of industry and commerce has created material for an important group of new sciences, has brought into existence many new businesses and professions, and created a corresponding need for special training for those who expect to play their part effectively in the new world of business. These new business training courses and the somewhat older engineering courses rest upon much the same line of defense, viz., the need of fitting young men and women for their life environment. For many lines of business the purely technical engineering course is the best preparation, for others the typical engineering course plus certain special studies calculated to broaden the view and give a deeper insight into modern business conditions is best, while for many lines of business an entirely different training is necessary.

While the recent great increase in the number of engineering students in our universities and technical schools is in accord with the spirit and needs of the age, and as such a tendency is not to be deplored, it is nevertheless true that there is a great need for broadening the training given in such schools. Fortunately this need is rapidly coming to be recognized quite generally. For example, this very subject attracted considerable attention at the recent summer conventions of the Institute of Electrical Engineers and the Society for the Promotion of Engineering Education. In fact, there seems to be a general awakening concerning the breadth of the field which the modern engineer is called upon to occupy and the corresponding need for his

broader training. Thus far the greatest demand made upon our engineering schools and departments has been for technical specialists—chemists, draftsmen, designers, electricians, machine engineers, power-plant managers, etc. This demand will probably continue to be a strong one, but the modern engineer must be something more than a mere technician, however skillful, if he would avail himself of the greatest opportunities offered by the industrial world today. More and more frequently nowadays the engineer is called upon to become the manager and executive of great enterprises. The world, and especially the United States, was never in greater need of industrial leadership. In all fields industries are suffering from a lack of men who are not only thoroughly familiar with industrial processes and technical details, but also have a broad view and a thorough business training. Many small industries, as well as large ones, are waiting for superintendents, managers and leaders who have something more than technical knowledge. Ambitious engineering students, therefore, should receive such supplementary training as will enable them readily and quickly to be developed into industrial managers.

There is also a growing demand for engineers in the sales and purchasing departments of our large industrial corporations. The graduates of the engineering departments of our own university are already finding lucrative employment as engineering salesmen to such an extent as to make it unnecessary to elucidate the opportunities offered in this field. It is not so well known, however, that the purchasing departments of large industrial establishments are already being invaded by the engineer. In most manufacturing plants technical knowledge can be made a very large factor in the advantageous purchase of raw materials and supplies, and in many lines of manufacturing an engineer, who at the same time has had a sound training in business administration, commercial geography and certain other subjects, makes a much better purchasing agent than one without his technical knowledge. The engineer is better qualified to make a careful and systematic study of the requisite qualities and characteristics of many raw materials; he can select the best and most suitable material for each particular function, inspect all such materials when delivered, judge the proper prices to be paid, secure quick deliveries and constantly watch for opportunities for betterment. This fact is coming to be

recognized and consequently there is an increasing demand for engineers as purchasing agents in some lines of manufacture.

This growing demand for engineers with a broad training for managers, superintendents, salesmen, purchasing agents and other positions, raises two questions. What are the most suitable subjects of study for such students, other than the merely technical? How is such instruction to be provided? Manifestly many subjects which would undoubtedly be very cultural and helpful must be left out of consideration simply because the engineering courses necessarily are so crowded with purely technical subjects as to leave very little time for other lines of study. A recent examination of the engineering courses of twelve representative institutions shows that an average of only about 12 per cent of the total credits was devoted to such subjects as English and modern languages, history, political science, economics, jurisprudence, accounting, etc., the remainder being purely technical studies and those directly related and fundamental to the technical subjects, such as mathematics, physics and chemistry. In our own university each of the four-year engineering courses requires four credits in English. The civil engineering course also provides for twenty-one elective credits out of a total of 125, the electrical engineering course for 12 elective credits out of a total of 126, the mechanical engineering course for 11 elective credits out of a total of 127. This meagre opportunity for electives necessarily bars out any such study of ancient or modern languages and some other cultural subjects as would be of any great benefit. What, then, are the subjects within the time limits of the engineering studies, as the courses are now constructed, which will not only broaden his culture but at the same time be most directly beneficial in fitting him for his future environment, for securing and efficiently filling the positions, other than merely technical, now opening in increasing numbers? The author of this paper thinks that the following subjects of study will best accomplish both of these desired objects: general principles of economics, elements of accounting, commercial and industrial geography, American industries, corporation finance and management, factory organization and management, transportation, money, banking, industrial history, and commercial law. The fact that many manufacturers are compelled to seek foreign markets for their wares also makes a study of foreign commerce desirable and even necessary for many of their em-

ployees. Of course few engineering students, with the available time at their disposal, can ever study all of these subjects; they must choose from them according to their tastes and with reference to the particular lines of work they expect to follow in active life.

Not only should our universities offer the above courses to all engineering students, but they should adapt such training to the needs and qualifications of such students. There are two general types of schools in this country for training engineers: (1) technical schools, pure and simple, such as the Massachusetts Institute of Technology and the Rensselaer Polytechnic Institute, and (2) the engineering departments of universities and colleges. In both types of school the environment of the engineering student is necessarily very different from that of students in the arts and science courses. The overwhelming preponderance of purely technical work necessarily required of the former tends to make it very difficult for them to study such subjects as those just enumerated in the same manner as the latter. Consequently the method of presenting such subjects to engineering students should be different from that used with arts and science students. The instructor should keep clearly in mind that engineering students who come to him for supplementary training are not seeking to become specialists in anything but their own line of work. Nevertheless general lecture or text-book courses in these supplementary subjects may be made none the less inspiring and broadening. Furthermore, even a general knowledge of these subjects will be directly helpful to the engineering student when he enters active life.

Just a word in conclusion concerning the opportunities for such supplementary training offered to engineering students in the University of Nebraska. The Department of Political Economy and Commerce offers a number of courses that cannot fail to be helpful to all engineering students who are looking forward to other than purely technical pursuits, and some of these courses would be very desirable even for those who do expect to be mere technicians. Besides Elementary Political Economy, Money, Banking, Finance, American Economic History, Insurance, Foreign Commerce, History of Commerce and Labor Problems, there are several courses that are very directly and intimately related to the work of engineering students, especially those who expect to become industrial managers and superintendents, or

employees in the purchasing and sales departments of industrial corporations. Among these may be mentioned Accounting, Commercial Geography, American Industries, Business Organization, Corporation Finance and Railroad Problems. In some of these courses an effort is made to adapt the subject matter and the method of presentation to the special needs and qualifications of engineering students. Quite a number of such students have already taken the courses and it is to be hoped that many more will do so in the future. In this way many will become much better fitted to secure and successfully hold certain desirable positions in the industrial world, for which merely technical knowledge does not adequately prepare.

THE FAILURE AND RECONSTRUCTION OF THE TUINUCÚ RIVER BRIDGE.

BY JOSEPH A. SARGENT, '03.

This paper is a non-technical exposition of the wreck and subsequent reconstruction of a bridge—the kind of a job that the maintenance-of-way engineer may be called upon to handle in any tropic country where a railroad, newly built under rush orders, finds itself subjected to a general test by flood. Such a job is worth talking about only for the lessons it teaches those who are willing to profit by the experience of themselves and others.

The rebuilding of a wrecked structure confronts the roadway engineer with a condition and a theory, with the latter in the back-ground or in abeyance until trains are running once more on schedule. Usually on a new railroad where the vital problem of existence is to make earnings pay interest on bonds and also cover operating costs, the maintenance engineer has his time so fully occupied with the details of daily routine that when he must add the handling of a special emergency job of some magnitude to his regular work, he has scant time to devote to the study of cause and effect. He must, therefore, anticipate accidents in any department of the service and in so far as he may, proceed to remedy them as soon as they occur.

After the nut has worked loose it is up to the roadway force as Kipling might say, to "put the two streaks of rust into place once more." It is a case where there is very little time to make comparative studies of "what to do."

In anticipating the handling of emergency duties the writer knows of no sounder counsel to be absorbed into one's brain fiber than the truth so often quoted by Theodore Cooper: "The most perfect system of rules to insure success must be interpreted upon the broad grounds of professional intelligence and common sense."

THE TUINUCÚ RIVER BRIDGE.

The Tuinucú river bridge lies on the Sancti Spiritus branch of the Cuba railroad, spanning the river of similar name. It is 330 feet in length over all. The original structure was sup

ported on steel towers having their footings supported on masonry pedestals. The top of each pedestal was built up to a level higher than previously-recorded high water.

The bridge is made up of sixty-foot deck girders between towers and thirty-foot deck girders over towers with a ninety-foot span deck Warren truss over the normal waterway of the river.

The towers were originally built with standard sway "X" bracing. The "X" bracing of the towers caused the failure of the bridge when subjected to extraordinary flood conditions. (Note sketches of the original structure and photographs showing accumulation of drift on the "X" braces.)

The Tuinucú river, like many other tropic streams, is subject to occasional floods that have their origin in heavy rains or cloud bursts in neighboring low mountains. The high gradients of the headwaters of the streams of this nature cause a rapid and violent run-off of storm-waters which it is difficult to estimate.

THE STORM THAT CAUSED THE FLOOD.

Beginning in the afternoon of November 6th, 1906, and continuing during the night and a greater part of the next day, we experienced a general deluge of rain that extended over practically all of our four hundred miles of track. If the rain had been furnished according to plans and specifications it could not have more thoroughly subjected our lines to the test by flood.

In some zones of the storm the sugar plantations reported that during one period of the rain nine inches of water fell during five hours. The rain-fall data, however, are subject to question, though the amount of water that fell was enormous.

A large percentage of streams in the storm area ran at random out of their banks. It speaks well for the good judgment of the engineers who located our lines that the lines they laid down were so true to natural drainage crests that, except for the failure of the Tuinucú bridge, we suffered only a few small embankment erosions that were quickly filled by extra gangs. Having over 450 miscellaneous waterways, bridges, trestles, culverts and cattle-passes, it is worthy of note that under the most severe flood test that seems probable we lost by flood less than one-quarter of one per cent of the structures subject to the test.

It is worth stating that the above small percentage of loss under the stress of such flood tests shows that tropic railroad can be so built as to compare very successfully, in ability to withstand floods, with railroads in our States where floods of the kind here described are seldom encountered.

The value of common sense drainage studies during location can hardly be overestimated, but very little that is sure and safe can be determined by consultation of empirical drainage formulae. In the first place, the tropic jungles make the cost of running around the average drainage area prohibitive, and other means than measuring drainage areas must be used to determine the sizes of bridge openings in regions where the jungles have not been cleared. It is the writer's opinion that conditions of general freshet such as carried away the Tuinuc bridge transcend all flood conditions that drainage area or runoff formulae are likely to indicate.

The writer believes that the best general method to locate heights of important bridges in a tropic district that is being opened to civilization by the building of a railroad under rush orders, is for the bridge engineer or reliable assistants to camp on the banks of the rivers during the "primaveras" and "temporales" of the rainy seasons. Let the engineers get up in the night if necessary to mark the high-water lines during local floods. The bridge engineer should also hold caucus with the local brotherhood of the Universal Society of High Water Liars that one is sure to find among the oldest inhabitants, if inhabitants there be. Take the mean level of the high-water lies, salt it a trifle with what you believe your own first-hand observations have told you, then raise your bridge level three meters above the probable mean you have selected in order that floating tree limbs may not reach up and pull your bridge from its seat.

Having thus studied your waterway, for a job where you are working overtime to get ready for the track and steel gangs, you may put in your steel work with prayers that it will stay until it rusts out. If the bridge fails after this, you can look wise and blame it to providence. The writer has come to this belief after having assisted at the obsequies of several tropic bridges that were located by engineers of unquestioned good judgment and international reputation.

As a matter of fact, nearly all tropic, inland, mountain-fed streams, unless they are bound by deep cañons, overflow the

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banks, so it can be usually accepted as axiomatic that the steel should be well above the banks, even where the banks rise fifty or sixty feet above the normal water level.

THE FAILURE OF THE BRIDGE.

In the accompanying sketches and photographs the rise of the river is shown, compared to the rise of previously-recorded high waters, also compared to low water.

The bridge failed due to the banking up of "Caña Brava" (local name for Cuban bamboo) and other floating debris. The sway "X" bracing of the steel towers caught the "Caña Brava," causing an entanglement that accumulated other debris, and eventually formed a jam.

The jam against each tower continued to grow until, when the accumulation of debris had gathered sufficient mass, the south tower failed by sliding off its pedestals, taking with it the upper masonry courses of the pedestals, as shown in the sketches and photographs, and the bridge was swept down stream by the current much as if it were a wisp of straw trying to out-face a Kansas cyclone.

In regard to the jam that carried away the towers, it should be noted that the only trees in Cuba that float are the soft-wood varieties. The native hard woods are so dense that they are heavier than water and therefore sink, except in some cases when they are partially buoyed up by becoming entangled with lighter debris, in which cases they may be dragged down stream in the middle height of the current or along the stream bed.

As there are over eighty varieties of Cuban woods of varying densities, when an unusual flood erodes the banks of the larger streams, it will be seen that the current may at times be carrying debris at varying velocities, from the light "Caña Brava" and softer woods on the surface to the denser hard woods moving in mid-current or dragging on the bottom. "Caoba" (mahogany) is one of the moderately hard woods. Compared to other native hard woods "Caoba" rates as second class for ties and bridge timber, and is then accepted only when there is a scarcity of the other native hard woods, which are superior to "Caoba" in longevity.

THE RECONSTRUCTION.

After due inspection of the steel wreckage where it had been playfully distributed over several acres of river bottom, it was

found that comparatively few rivets had been sheared. The only parts that had twisted or bowed or buckled while subjected to the force of the current were a few minor members, struts and lattice work. Each major member of the girders and truss had fortunately not been distorted to an appreciable amount.

A new bridge was roughly figured on for comparative purposes, but considering the fact that we had the old steel, free in the river, except for the labor cost of salvage, it was decided to redesign and reconstruct the piers and reassemble the old steel in its original position with the exception of eliminating the sway "X" bracing which had formed the jam and caused the bridge to fail.

It was found that by reconstructing the bridge by using the old steel, replacing with new steel from our shops the injured minor members and lattice work, and by reconstructing the piers (as shown on the accompanying sketch of the new piers), we could save upwards of 30 per cent of the cost of a new bridge and also have what is believed to be a safe structure.

The remains of the old piers were found to be in safe condition, having been built upon native hardwood pile clusters, with all points of cut-off under water, needing only the depositing of rip-rap around the base of the piers to prevent undercutting of the river bed, and it was decided to use the old piers as cores for building up new reinforced concrete piers to a level well above the newly-established high-water mark. (Note accompanying photographs showing reinforcement to secure bond between new concrete and old masonry).

At the time we were obliged to reconstruct the bridge, United States steel manufacturers were rushed with orders and were asking for ninety days' notice before fabricating steel for new orders, so the decision to pick up and reassemble the old steel in the river, besides costing less than a new bridge, offered us the most expeditious method of putting the bridge over the Tuinucú river to work.

THE TEMPORARY TRESTLE.

As soon as timber could be hauled to the bridge site a temporary trestle was built to serve a double purpose: to accommodate train traffic at the earliest moment and to serve as false work for rebuilding the bridge.

The temporary trestle, as built to let trains over provisionally,

was of course much heavier than would have been necessary if its duties had been limited to serve as false work for steel erection. In order to operate trains we were obliged to take the chance of the occurrence of another flood before the duties of the temporary trestle were ended. Fortunately the dry season set in almost at once after the big flood, and our gamble on the stability of the timber structure was not put to the touch.

The lower half of the trestle was made up of standard pile bents. The piling were of native hard woods and were driven by a pony driver, with engine and boiler assembled on a small, portable frame work, so that the pile driving outfit could be skidden ahead, bent by bent, as fast as respective bents were driven and capped.

The upper story of the trestle was built up of framed bents, also of native hard woods, mahogany or woods of better grade. The framed bents had their sills spiked to the caps of the lower pile bents. The deck of the lower pile bent story was used as a staging upon which to knock together the framed bents for the upper story of the trestle. When the bents were all framed, each bent lying with its sill over the cap to which it was later to be spiked and each bent lapping shingle-wise over the next bent ahead, the entire upper story was readily erected by raising the bents and tilting them into place, 1, 2, 3 order. (See photograph of derrick car at work just before closing the south end of the temporary trestle.

SALVAGE AND REASSEMBLING OF THE STEEL.

It was at first thought that some of the girders, as well as the 90-foot Warren truss could be fished from the river and skidded bodily into their respective seats on abutments and piers, but this idea was abandoned in order not to take any chances with weakened rivets and minor members or twisted lattice work. The 90-foot truss was skidded up on the river banks, but all minor members were scrapped. Rivets were cut, faulty minor members replaced from stock steel, and the bridge was reassembled member by member, each one being carefully inspected to see that no faulty steel was permitted in the reconstructed bridge. New rivets were used throughout, as the old rivets had to be cut during the scrapping of the original members.

COSTS AND LESSONS LEARNED.

The writer is not at liberty to quote unit costs, as the work was done by a private company. All work was done by extra gang and by direct administration.

The writer does not for an instant undervalue unit costs, and he has a keen appreciation of their value in preparing alternate estimates of works in project when the conditions governing units of cost are thoroughly understood and digested. He believes, however, that unit costs are neither an unfailing fetish nor a cure-all. Not for a moment would he wish to be understood as scoffing at the jealous little god of economy, but in a mud and water job of the emergency nature herein described the greater economy always consists in not forgetting that the running of trains is of more value than a few units saved here and a few units there by penny-pinching, pound-foolish methods. Under stress and tension of emergency work many units of effort are likely to be duplicated, causing double units of minor costs wherever effort and material needlessly overlap. This always has been, and probably always will be, the case on emergency work, as long as best laid plans of mice and men go on the bias. It is of course the engineer's duty to cut out useless duplication of work and material.

The emergency jobs on reconstruction, as the man from India might say, are up to "Martha's sons." They must go down into the pit and root in the mud and sand, pull the steel out of the wreck and put it back where it was before; and when they are on the job they have no time to wait for the spirit to move them. Each man has to do the moving for himself.

Unit costs, as too frequently they are quoted to the man with fresh mud on his boots, are a thorn in the flesh unless taken with a large amount of discretion. After the remedy for the "trouble" has been decided, assuming that the initial diagnosis has been made with judgment and horse sense, the success of the work rests upon the untiring effort of two or three good men, who must do all the planning, all the anticipating of necessary labor and material. The superintendent of construction and his bosses must camp on the job.

There can be no diletantism permitted to creep into any part of the task at hand. In a superintendent or an engineer the slightest whit of uncertainty confuses the men and the work as surely and fatally as would the loss of the dominant mind

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in time of battle. And the men on the job must dig in their toes, wade in deep and take hold with their whole hands and shove. It is up to them to "get the jump on the weather" and drive the work when progress seems like a dead weight hanging back on their hands.

Oftentimes the working gang is cheered on by an aggregation of "Mary's sons," who fume and talk loud of what the railroad commission should or may do to someone or other to get square with the "Co." for the prejudice and damages caused the traveling public by the failure of scheduled trains to fulfill their obligations. This class of prominent citizens undoubtedly mean well, but their method of friendly suggestion is seldom received in a proper Christian spirit by the extra gang working up to their waists in mud and water, although the maintenance engineer will always try to keep heart in the boys in the ditch by taking the blame for delay on his own shoulders. As civilization is now constituted, he is likely to have to do so, whether he likes it or not, so he had best be game and accept it voluntarily and not take his eye off the job.

In the reconstructing of the Tuinucú river bridge the trains were run over the temporary trestle during the building up of the new piers and the reassembling of the steel; but all trains were run over the bridge at four kilometers per hour while the concrete was green, to reduce vibration to a minimum.

The work was under the direction of the writer, as engineer of roadway. Mr. W. O. Ayer, a University of Nebraska man, was principal assistant engineer at the time and rendered valuable service during the flood, as well as during reconstruction, as did also Messrs J. H. Rousseau and Andrew Davis.

About two-thirds of the labor on this work was made up of Spaniards, Gallegos and Catalanians; the remainder, except for superintendents, was of native Cubans. The bridge was reconstructed during the *zafra*, or sugar, season. In this season the sugar plantations are seeking far and wide for labor, sometimes offering better than standard wage scale, and men who understand sugar work are hard to hold. Gallegos and Catalanians, however, if paid regularly and given steady work, are exceptionally faithful men. They will follow a boss who knows his business just as long as he stays with them. They are not always accustomed to our methods of work, but are willing and anxious to learn new methods, if they have a masterful boss who will

take the time and keep his temper while moulding them to the needs of the work.

A FEW WORDS TO THE YOUNGER BROTHERS.

If an elder brother may presume to offer a few words of counsel to the younger brothers of the profession, though I know unsolicited advice is usually of questionable value, I would invite you to note that the islands of the Caribbean sea, the republic of Mexico and all of South America are now one vast theater of progressive constructive enterprise. The day of the finding of hidden pirate treasure has long since gone by, except in romantic novels, and the day of the financial adventurer and soldier of fortune is rapidly waning. The countries of the eternal *manana* are stirring in their dreams. It is being whispered that a great canal is being cut between two continents that will bring into the world a new era. These are, in truth, lands where every prospect pleases and only man is vile. In the next fifty years these countries will make greater strides than will our own, for they are pitifully far behind in mechanical and scientific fruits of civilization, though in some of the "humanidades urbanidades," we are a century behind the Spanish in precept and in act.

There is and will continue to be a crying need for trained men in the tropic countries. The men who answer the call "Men Wanted" (and you can rest assured that some few of the younger brood will want to try their wings) must go prepared to accomplish twentieth century tasks, often with the aid of sixteenth century men, who have suddenly found themselves confronted with our ruthless law of the survival of the fittest. The dictators of thought in the Latin American countries are teaching the rising generation that they must climb or perish, and the ladder of heaven is taking hold. Some of them are beginning to work as their forebears, since the days of the strenuous Cortez, never worked.

These people must have the help of men trained to the house who are strong in working power, of unquestioned moral courage and integrity, who are sensible and unselfish. The man blessed with these qualities, who holds no necessary working task and no humble worker in supercilious disdain, may hope to succeed where the many fail. In these lands now opening to our peculiar civilization the need of such men is legion, and the reward will be in proportion to the goods delivered.

The good workman dare not despise his tools, be they peon laborers, ninety-ton steam shovels, or the language and the understanding of the people where he must earn his bread. The young engineer who comes to the tropics must learn how to live a rigidly cleanly, sanitary and upright life in the midst of wretched poverty and squalor, if he is assigned to duties in the interior. Some of the cities can give our northern civilization pointers in sanitation, but the rural districts are still in the Dark Ages.

If you go into tropic service, all the practical points you can get on camp sanitation, proper cooking of plain foods, meats and vegetables by broiling, roasting and baking, are information that is golden. From observations made in Mexico and in Cuba, it has been my experience that a normally healthy man who does not eat grease and garlic, who leaves strong drink alone, and who never backslides in the maintaining of sanitary camps, seldom loses his health beyond light acclimation fevers, unless he is distraught from overwork and permits himself to worry.

Unfortunately many of our northern young men when they leave home behind seem to think they are in duty bound to measure their capacity to drink the famous rum made by Mr. Bacardi, who probably has more serenades sung in his honor than any other man in the sub-tropics; but the sensible man is he who cuts it out.

As to the Spanish language. It is a pity to see, as I have frequently seen, one of the best products of the North American university from, say, any school between blue-nose land and the Golden Gate, sent into the interior and turned loose to handle his first responsible job.

If he does not know his Spanish and has no interpreter (and the average interpreter is usually too vague for precise and urgent work) a painful tableau ensues, to be continued for from three to six months, depending upon the man's facility in learning bastard Spanish. Confused native foremen and *capataxes*, more or less anxious to please and to a limited degree in fear of the fists of the "Jefecito Nuevo," and all of them in urgent need of intelligible instructions, stand with shrugging shoulders, making apologetic gestures of sympathy or grinning open ridicule. The perspiring "Jefecito Nuevo" finds himself in the class of the deaf, dumb and blind, without knowing the dumb alphabet.

In trying to explain his orders he waves his arms and legs, jumps up and down in the air, usually calling upon his vocabulary of stock and original profanity, scratches pictures in the dirt with a stick, and all in all, gives a fair imitation of a Crow Indian making medicine. He usually comes to the conclusion that it is a godless country, in which the people are all fools or worse, and his suffering subordinates hold somewhat mutual feelings, but contrary opinions to the effect that "casi todos de los Americanos son locos." The whole performance causes the hapless and helpless new boss to search his soul for picturesque swear words, all because his Spanish is limited to "Buenos Dias, caballeros," "Gracias, Senor," and "Adios, mi amigo," which are too mild to suit the needs of the minute.

The writer would not for one moment advise the cutting of your French or your Deutsch, which are, as ever, the idioms of diplomacy and philosophy; but he would urge you to make any sacrifice within reason to learn the language of the countries wherein we will conduct the heaviest percentage of our future trade.

Paraphrasing a current humorist, I believe it can be said in truth that for the engineer Spanish will be of value, if only considered from the low, vulgar and selfish standpoint of MERE USEFULNESS.

When you are called to a construction job in the tropics, every word of useful Spanish at your command will be a balm of joy to your overworked colleagues, for you can thereby share their tasks.

Looking northeast from south bank of river. Note the 90-foot Warren deck span in river. Also note the single rail suspended in air and held together by angle plates.

Looking northwest. Note erosion around bottom of pedestals and drift on tower.

Temporary trestle just before being closed. Note pile driver apparatus for driving lower story of trestle in center left of view. Engine and driver on movable frame to be skidded ahead after driving each bent.

Work train just after closing end of temporary trestle.

Beginning of reconstruction before the steel towers were replaced on piers.

Showing reinforcement to secure concrete bond at the level of the foot plate of the steel tower which is shown in place ready to be concreted into reconstruction of pier.

Steel tower in place, looking upstream.

Reconstructed piers finished and forms removed.

Bridge complete and open for traffic, looking downstream.

THE EFFICIENCY SYSTEM AS APPLIED TO THE WAGE EARNER.

BY BRUCE W. BENEDICT, '01,
Supervisor of Schedules, Santa Fe System.

Economical shop operation is secured by effective supervision and control of the three following elements:

- (a) Labor.
- (b) Material.
- (c) Shop charges.

The first item (a) includes the cost of the labor necessary to perform all operations from the time the raw material enters the plant until the finished product is delivered. The second item (b) represents the investment for material required in the manufacture of the product. The third item (c) or shop charges include the expenses of operating the plant, depreciation of machinery, tools, etc., and all surcharges incident to manufacture. These factors compose the entire charges of shop operation and manufacture of product. Each bears directly on the performance of the plant, the output and the cost of production. The highest economy and efficiency is essential in each of these branches of shop operation and the same degree of supervision must be extended over all to keep a proper balance between departments and maintain the standard required in each. Without this broad supervision, the economies of one branch are offset by the wastes of another, and the final result is low output efficiency and high production costs.

It is obvious that each one of these branches is worthy of individual investigation and treatment. In actual shop management the three branches cannot be disassociated, but in this paper one phase of the problem, namely labor, will be considered to show one method of securing the highest efficiency from labor to the entire satisfaction of both employer and employe.

In shop operation the labor question must be considered from two sides: (1) the employer who pays the wages, and (2) the employe who receives the wages. The first exchanges money for labor and the second exchanges labor for money. It is natural

that the man who has labor to sell wishes to sell it for the highest possible price and it is equally natural to expect the man who buys it wishes to obtain the greatest return for the money spent. As a statement of cold facts it might seem as though the interests of the two sides were opposed beyond the possibility of reconciliation, but actual experience shows that harmonious relations are readily established between the two. If the employer is able to keep the cost of production within a reasonable figure and the employe receives satisfactory wages it is evident both have realized the individual benefits of commercial partnership.

Under the old system of paying for labor on the hourly or daily basis this harmonious condition does not always obtain, as employes prefer to have wages on a flat scale, paying the same rate to all men on the same class of work. This plan does not recognize efficiency of the men, nor provide a wage rate consistent with their output, but it arbitrarily places workmen on an equal basis regardless of actual worth. Under these conditions unit costs are usually higher than they should be, as a certain percentage of the workmen are more or less incompetent and their work is below normal in regard to output and quality. The employer therefore is paying out wages for time put in, regardless of the work performed. It is obvious the employer does not have an absolute check or control production costs and it is doubtful if he is in a position to demand and secure an output from his workmen consistent with the wages paid. For this reason the employer is generally willing to pay wages on output, even though a higher rate per hour must be paid for more efficient labor.

Under the day wage system the cost of an operation is the product of the hours worked times the rate per hour. This is shown graphically by the diagram in Fig. 1. The wage line of the diagram shows that the cost of an operation increases proportionately to the hours worked. This wage line therefore represents the cost of one operation performed in 10 hours by a workman receiving 30 cents per hour, but it does not represent the average cost or the standard cost of the operation by another workman, as the cost is purely a function of the time employed in completing the operation. The next time the operation is performed the time consumed may be 9 hours or 11 hours, which will vary the cost from \$2.70 to \$3.30. Clearly the employer cannot control the cost of production under such

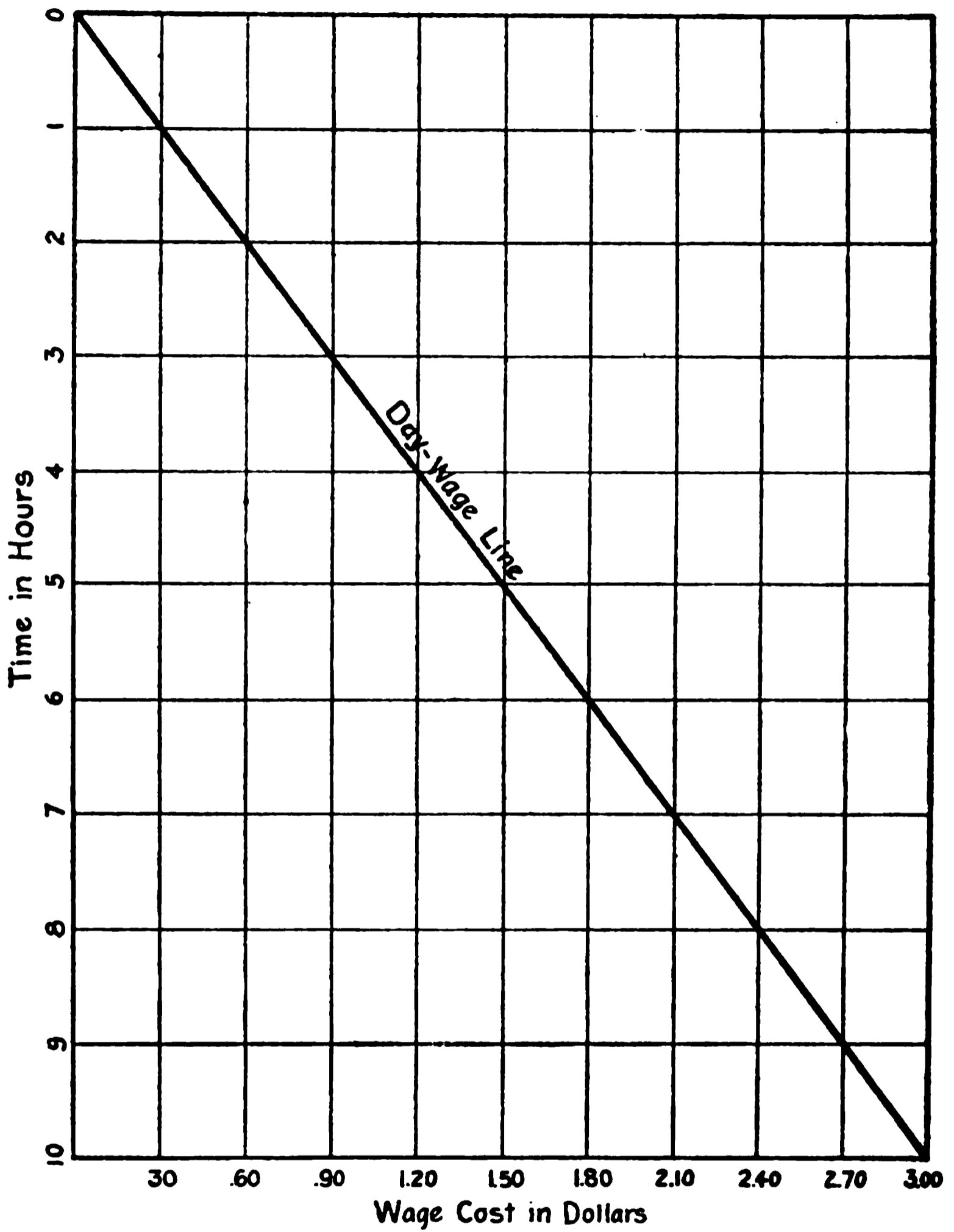


FIG. 1.

Diagram illustrating day-wage method of paying labor. The cost of an operation is the product of the rate by the time.

conditions, nor can he with any degree of certainty maintain unit costs and volume of output.

As a gradual realization of the inefficiency of the day work system was forced on the shop managers, other methods for the payment of labor were devised and introduced into shop operation. The first plan to win more or less general recognition was "piece work," or payment of a fixed price for each operation performed. This plan offers a number of advantages over the old day rate method, as the workman receives wages somewhat in proportion to his efforts and the employer pays a wage rate based on output. Theoretically this is an ideal system for both parties concerned, but the results of actual experience disclose a number of faults which cast considerable doubt on its value as a wage system.

The diagram in Fig. 2 is a graphical illustration of the piece rate system and the wage rate per hour paid for labor when the work is performed in different periods of time. The diagram is arranged on the assumption that the piece rate is \$2.40 for an operation, with labor rated at 30 cents per hour. It will be observed that the workman taking 8 hours for the operation will just make his rate of 30 cents per hour. If he takes 10 hours he will receive 24 cents an hour and if he uses only one hour his rate will be \$2.40 an hour. It is assumed that the operation would take 10 hours, to perform which at the hourly rate would cost \$3.00, so the employer will save 60 cents, or 20 per cent in wages by paying for the operation on the piece work basis.

The piece rate is fixed but the conditions to which it applies are constantly changing. Obviously the piece rate does not always cover the conditions, as it is sometimes too high for the work done and sometimes too low. In either case, the piece rate is not a legitimate one and cannot be considered as the established price paid for performing an operation. As the rate for the operation is fixed, all delays due to break-downs of machinery, waiting for material, etc., necessarily increase the time taken to do the operation at a direct loss to the workman. Thus all inefficiencies of shop operation and management are paid for out of the wages of the men, when the management as the responsible party should rightfully shoulder the expense. In practice, the piece rates have generally been juggled at the will of the employer, which has militated against the system to such an extent that the term "piece-work" is now generally recog-

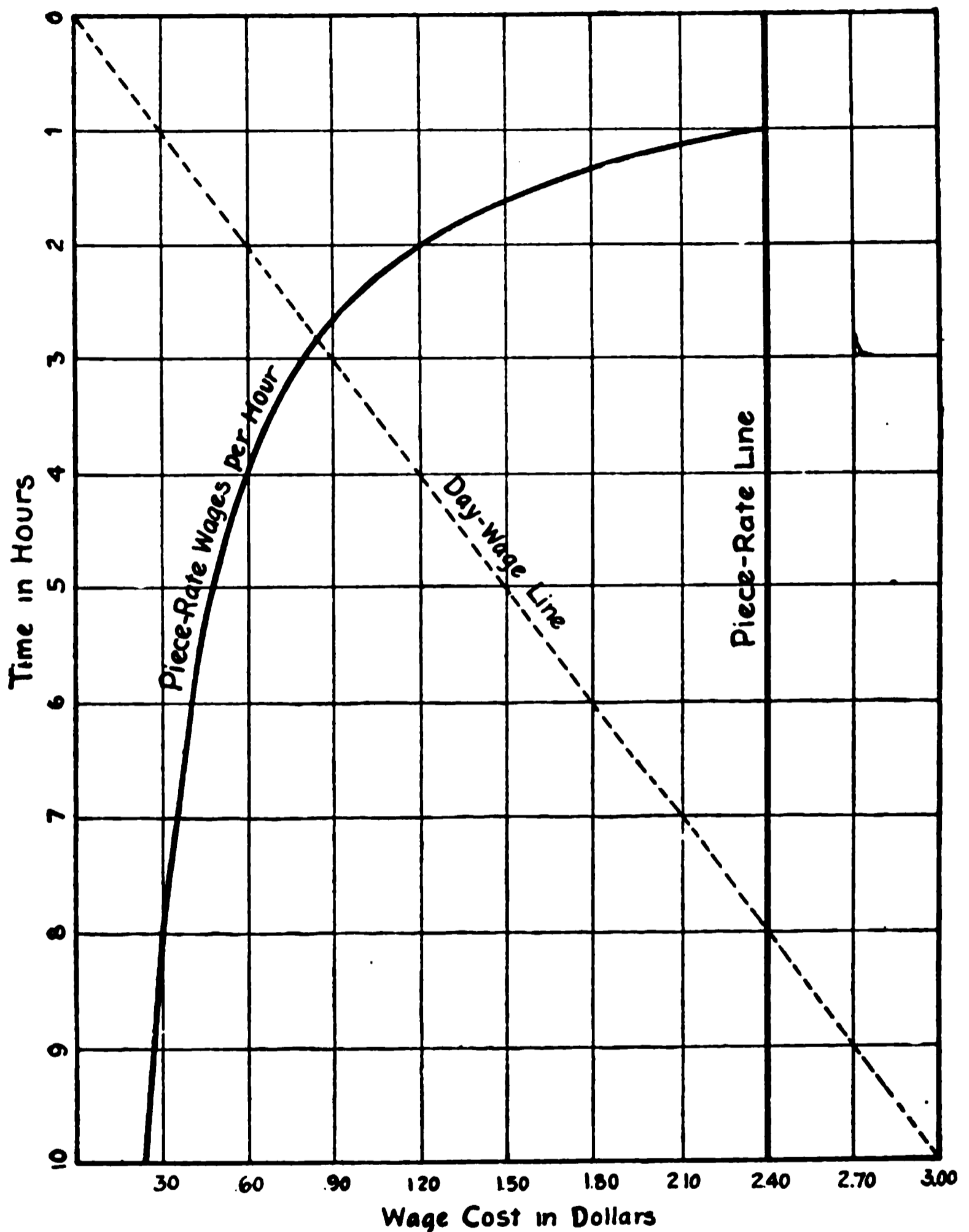


FIG. 2.

Diagram illustrating the piece-rate method, with wage rate per hour of workmen performing a given operation in times varying from 1 to 10 hours.

nized as the synonym for unfairness. While the payment of wages on the piece-rate basis is a step in advance of the day-rate method when properly handled, the inherent faults of the system render it unsatisfactory from the standpoint of both parties as an equitable wage contract between employer and employe.

In the evolution of wage systems and in the endeavor to get away from the inefficiencies of the day-rate and piece-rate systems, the so-called "premium" wage plan was gradually evolved. In general, the premium plan is a modification of the day-rate and piece-rate systems, with the aim of retaining the good features of each and avoiding the detrimental qualities known to exist. Briefly, a premium wage system allows the wage earner a certain rate per hour as on the day-rate basis but offers a stimulus for extra output by sharing with him a certain percentage of the time saved in the performance of his work. By shortening the time for each operation the workman will increase his output and consequently receive a greater wage rate per hour. There are a number of premium systems in operation that are giving admirable results in regard to shop operation, costs of production and as a satisfactory method of paying labor.

The latest development in wage systems is the "efficiency" plan as applied in the locomotive and car shops of the Santa Fe Railway. As implied by the name, the fundamental principle of the system recognizes the efficiency of the workman as the natural basis for determining his rate of pay. The system provides for the interests of both parties by affording the employer a low unit cost of production and the workman a wage rate commensurate with his ability. The injustice of the day-rate to the employer and the piece-rate to the employe is transformed into a community of interests in which the benefits are equally distributed.

The Efficiency System is a combination premium day-rate plan. It combines the satisfying stability of the day-rate system from the labor standpoint, with the more accurate and scientific features of the premium plan so acceptable to the employer. The workman is sure of receiving his regular day-rate and the employer is assured of an output proportional to the money spent for wages.

In the Efficiency System the standard time for performing each operation is accurately determined. This standard time, so

called, is the time in hours and tenths an average workman takes to do an operation with reasonable effort but without wastes and delays. It represents average performance of a good workman. When a workman performs an operation in the standard time, his efficiency is 100 per cent and he is allowed 20 per cent of the day wages received while on the operation as a bonus for performing the operation in the standard time. If more than standard time is taken to do the operation, the efficiency of the workman is less than 100 per cent, with a decreasing bonus reward. When the standard time is exceeded by one-half, the efficiency of the workman is 66.7 per cent and no bonus is earned, as at that efficiency the economical limit of operation is reached. If the workman is able to perform the operation in less than the standard time his efficiency will necessarily be above 100 per cent and the bonus reward correspondingly greater than 20 per cent. Thus the workman receives his daily wages and in addition a percentage of them extra as a reward for performance above 66.7 per cent efficiency.

For accuracy and convenience in determining the bonus earnings of workmen, a standard efficiency table is arranged giving the equivalent percentages of wages allowed for efficiencies above 66.7 per cent. In using the table the efficiency of the workman is first determined by dividing the actual bonus worked during the month, into the standard hours accumulated during that period. The bonus percentage corresponding to this efficiency is then read directly from the table and the bonus earned calculated. The table shows the bonus percentages for efficiencies by 0.5 of a per cent from 66.7 per cent up. Above 100 per cent efficiency the bonus percentage increases in regular increments of 1 to 1 per cent efficiency, while below 100 per cent the increment is somewhat different as shown by the following examples taken from the table:

| Efficiency per cent | Percentage of wages as bonus |
|------------------------|------------------------------------|
| 66.7..... | .0 |
| 70 | .22 |
| 80 | 3.27 |
| 90 | 9.91 |
| 100 | 20.0 |
| 110 | 30.0 |
| 120 | 40.0 |
| 130 | 50.0 |

It is obvious that a reasonable effort on the part of the workman will result in a greater wage rate per hour, with no penalty for poor performance except a loss of possible earnings. The workman, therefore, is in direct control of his wage rate: by cooperation with employer in eliminating wastes he receives a bonus in proportion to his efforts, and from failure to do so he forfeits the premium and receives only his regular wage rate. Thus the only penalty exacted of the workman for poor performance is self imposed through lack of the necessary effort.

In actual practice the efficiency of the workman is not determined on each operation separately and his earnings calculated on that basis, but his performance for a period of one month is averaged and the bonus earnings apportioned on the average efficiency attained for that time. Thus the workman must maintain a steady and efficient daily performance in order that the average efficiency of the month will insure a suitable reward in bonus earnings. The output of a steady workman is greater than the erratic workman and the results obtained from that class of labor are the most satisfactory from every point of view. By averaging the monthly efficiency of each workman the efficiency of separate gangs, departments and the shop as a whole is obtained. The costs of operation are thus accurately determined and standardized.

The diagram in Fig. 3 is a graphical illustration of the Efficiency System and represents the costs of performing an operation at various efficiencies and the earnings of the workman under different conditions. As in the previous figures the diagram is based on the performance of a workman receiving 30 cents an hour. The efficiency wage line shows the amounts received by the workman as total earnings when operating at efficiencies ranging from 66.7 to 667 per cent. Under the efficiency plan the earnings of a workman are made up of two elements, *i. e.*, hourly wages and the premium or bonus. The hourly wage line is plotted to show the day-rate wages, and it divides the total earnings of the workman shown on the diagram into the elements mentioned, according to the actual value of each. It is assumed that the standard time for the operation is 6.7 hours, so if the workman performs the operation in that time, his efficiency is 100 per cent and he will be entitled to 20 per cent of his wages extra as a bonus. At 30 cents an hour the day wages for 6.7 hours is \$2.00, and 20 per cent of this is

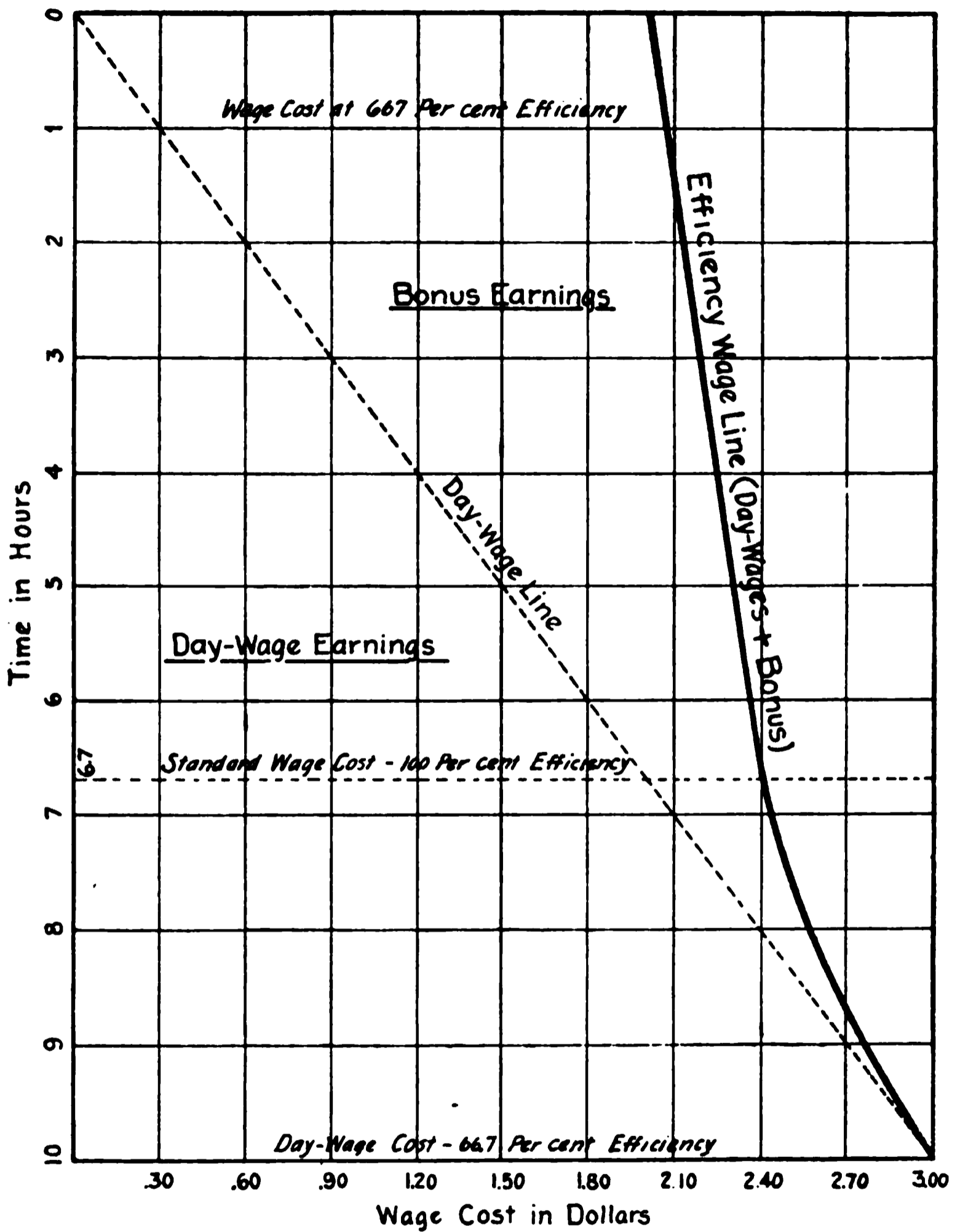


FIG. 3.

Diagram illustrating the Efficiency System and the relation between efficiency of performance and wages. The premium paid as bonus earnings to the workman for efficient performance and the decreasing unit costs of labor at the higher efficiencies is plainly shown.

\$0.40, so the workman receives \$2.40 for performing the operation in standard time and his wage rate increases from 30 to 36 cents an hour.

When the standard time, as previously stated, is exceeded by one-half, or the time actually taken by the workman is half again as long as the standard time allowed, the efficiency of the workman is 66.7 per cent and no bonus is earned. As shown by the diagram, 10 hours is required by a workman operating at 66.7 per cent efficiency to perform this particular operation. The total cost of the operation at this efficiency will be \$3.00 for 10 hours' work at 30 cents an hour. The employer therefore pays \$3.00 for the operation which at 100 per cent efficiency cost only \$2.40, besides receiving only one-half the output from the workman. The latter earns 30 cents an hour as against 36 cents an hour at 100 per cent efficiency.

On the other hand, there is a direct advantage to both parties in high efficiency. A good workman may be able to reduce the standard time one-half. If, for instance, the standard time of 6.7 hours is reduced to 3 hours by extra effort on the part of the workman, his earnings for the operation according to the diagram will be \$2.18, of which \$0.90 is wages and \$1.28 is bonus. Thus from a cost of \$3.00 at 66.7 per cent, or the average day-rate performance, the cost of the operation is reduced to \$1.28, or 130 per cent to the employer, who also receives over double the output from the workman. The latter also advances his hourly wage rate from 30 to 72 cents, or 140 per cent, and his ability as a wage earner is increased in just that proportion.

It has been shown that both employer and employe participate in the financial benefits of the Efficiency System, the former by lesser unit costs and the latter by increased wage rates per hour. The diagram in Fig. 4 shows this even more clearly by representing graphically the relative costs of an operation performed at efficiencies ranging from 45 to 180 per cent. The operation represented in the diagram has a standard time allowance of 250 hours. That is, a workman completing the operation in 250 hours has an efficiency of 100 per cent and is entitled to 20 per cent of his wages extra as a bonus for performing the work in that time. The cost of the operation at standard time of 250 hours with the wages of the workman at 36 cents an hour is $250 \times 36 + 20$ per cent bonus equals $\$90 + \$18 = \$108$ or the

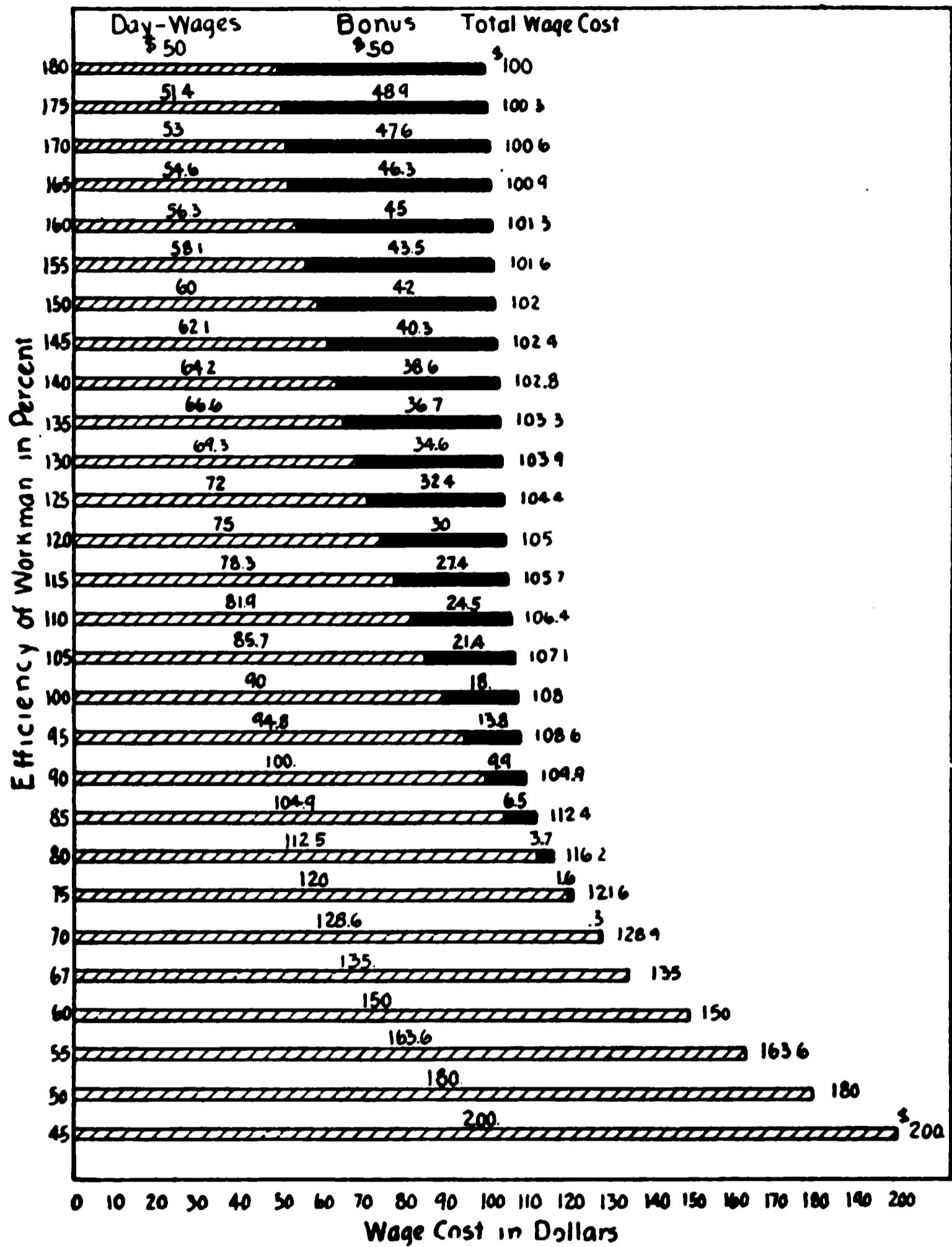


FIG. 4.

Diagram showing actual labor costs of one operation performed at efficiencies from 45 to 180 per cent. At 180 per cent the cost is one-half what it is at 45 per cent, the operation is completed in one-fourth of the time and the workman receives double the wage rate per hour.

standard cost. If for any reason the workman operates at less than 100 per cent efficiency the cost of the operation is greater than \$108, as shown by the diagram. At 66.7 per cent the point is reached where no bonus is paid and the cost of the operation is \$135 for day wages. At 45 per cent efficiency, the lowest shown on the diagram, the workman uses 555 hours to complete the operation and the cost is \$200 in day wages alone or nearly twice the standard cost. Thus the day-rate workman with no incentive for extra effort uses over double the time allowed for the operation under the efficiency standard, and the cost is 85 per cent greater than it is at standard performance. A day-rate shop operating at 45 per cent efficiency is not uncommon, so the loss in output and excessive production costs shown by the diagram is a reality in actual practice.

Above 100 per cent efficiency the cost of production decreases and the output per man increases. At 180 per cent efficiency the cost of the operation is \$100, of which \$50 is for day wages and \$50 for bonus, while the operation is completed in 139 hours, or 111 hours less than standard, an increase in output of 80 per cent. Comparing the performance of workmen at high and low efficiencies, it will be observed at 180 per cent efficiency the cost of the operation in wages is one-half what it is at 45 per cent and the output is practically 300 per cent greater. Thus the efficiency system gives the employer a large output and low unit costs, and the workman greater wage earning capacity.

A few figures taken from the diagram are given below in order to present in condensed form for comparison the costs of performing the operation at various efficiencies:

| Efficiency per cent | Total wage cost | Hours required to complete | Wage rate per hour |
|------------------------|--------------------|-------------------------------|-----------------------|
| 180 | \$100 | 139 | \$0.72 |
| 140 | 103 | 178 | .58 |
| 100 | 108 | 250 | .43 |
| 66.7 | 135 | 375 | .36 |
| 45 | 200 | 555 | .36 |

These figures emphasize the statements made in explanation of the diagram that at high efficiencies the unit costs are lower, wage rates higher and output greater than under the less efficient conditions usually existing in day-wage shops.

As previously pointed out, the performance of workmen in

Shop Hours

FIG. 5.

Diagram illustrating the performance of a workman for one month. The full line shows the actual time worked and the broken line the standard hours' work completed. Workman's efficiency for the month is 115 per cent.

day-wage shops is an indefinite quantity, depending upon factors over which the employer has little control. In the efficiency system this condition is reversed, as the diagram in Fig. 5 plainly shows. This diagram represents in graphical form the performance of an individual workman. The solid line shows the actual time worked daily and the broken line the standard schedule time of the operations the workman was engaged upon. It will be observed that the workman during the first portion of the month, or until the 18th day, failed to perform his work in standard time, as shown by the relative position of the two lines. For this period his efficiency was less than 100 per cent. On the 19th day, however, his performance began to improve and from that time until the end of the month it showed a steady and consistent improvement. At the end of the month the actual or hourly time of the workman amounted to 218 hours and the total standard time accumulated was 250 hours. That is, the workman during 218 actual hours spent in the shop performed work, which at the standard time allowed by the schedules, gave him 250 hours to accomplish. The efficiency of the workman was therefore 115 per cent, and is found by dividing the standard by the actual time. According to the provisions of the standard efficiency table, the workman in this case is entitled to 35 per cent of his monthly wages extra as a bonus for performing the work at the rate of 115 per cent efficiency.

Diagrams similar to the one in Fig. 5 are made out for gangs, shops and the entire plant, so the efficiency and performance for all departments can be accurately determined. Other records giving complete information of shop operation are arranged in connection with the efficiency system which under the day-rate method are impossible.

In the Efficiency System the accurate determination of the workman's output is one of the first essentials. The success of the system in actual shop operation will be measured by the manner in which this feature is organized. Each operation from the smallest to the largest must be accurately scheduled. A schedule is a complete description of the various details in each shop operation, with the standard time allowed in hours and tenths. The workman performing an operation will then have a definite amount of work to do and a fixed time to do it in. His efficiency will be determined by the facility with which he performs the work outlined by the schedules.

The successful operation of the Efficiency System is dependent upon the cooperation of both the employer and employe. The former must provide an effective organization and operate the shop in an efficient manner, besides furnishing the workman with suitable tools and facilities. On the other hand, the workman must cooperate with the management in making the operation of the shop as efficient as possible. With the cooperation secured, the efficiency system is a more satisfactory bond between employer and employe than the usual signed contract for the protection of rights.

While the shop operated under the Efficiency System is not immune from some of the troubles incident to the commercial relations between labor and capital, the outbreaks due to the clamors of selfish interests so common in ordinary shops are eliminated. The Efficiency System merges the interests of employer and employe into a common purpose leading to efficiency and economy, from which each reap an equal profit.

IMPROVEMENT OF POWER FACTOR BY ROTARY CONDENSER.

BY F. L. HUNT, '02.

The alternating current that flows in a circuit, where there is some inductance, such as the windings of an induction motor, or transformer, or even the self inductance of the wires themselves, is the resultant of two components.

(1) The energy component which is in phase with the impressed E. M. F. or voltage of the circuit, and which we say carries the energy; and

(2) The magnetizing or wattless current which lags 90 degrees behind the phase of the impressed E. M. F. and produces the magnetization in the iron cores of the motors or transformers, or in the space surrounding the wires of the circuit.

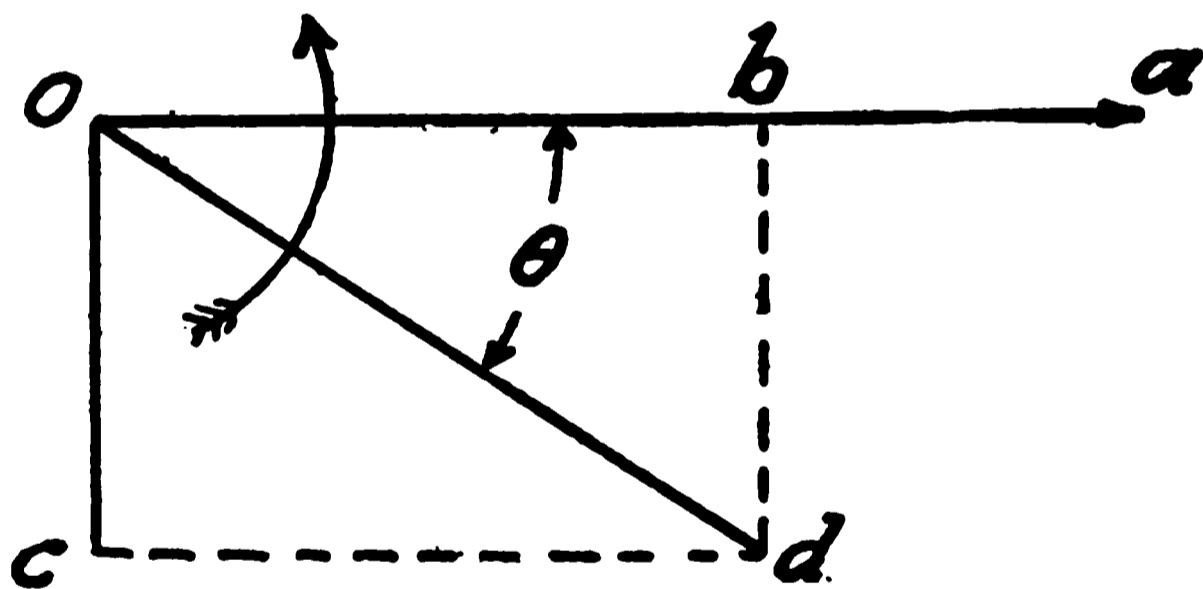


Fig. I

Referring to Figure I:

oa = impressed voltage or electro motive force E. M. F.

ob = energy component of current in phase with E. M. F.

oc = wattless component of lagging current.

The resultant of " ob " and " oc " is " od ," the actual current flowing in the line, and " od " bears the following relation to the two components:

$$\overline{od}^2 = \overline{ob}^2 + \overline{oc}^2$$

$ob = \cosine \theta \times od = \text{energy component.}$

$oc = \sin \theta \times od = \text{wattless component.}$

$\theta = \text{the angle "dob" which is known as the angle of lag of the current actually flowing.}$

The current that flows in a circuit where there is some capacity or condenser effect and no inductance is made up of two similar components, except that the wattless component is 180 degrees in phase relation from the wattless component due to inductance in a line. The resultant current then has a phase position similar to "oh" in Figure II and the angle "aoh" (θ_1) is called the angle of lead.

The ratio $\frac{ob}{od}$ or $\frac{of}{oh}$ is called the power factor of the current flowing.

$\frac{ob}{od} = \cosine \theta$ and $\frac{of}{oh} = \cosine \theta_1$, so that we say the power factor of a current flowing in a circuit is equal to the cosine of the angle of lag or lead, and the wattless component is equal to the sine of the angle of lag or lead.

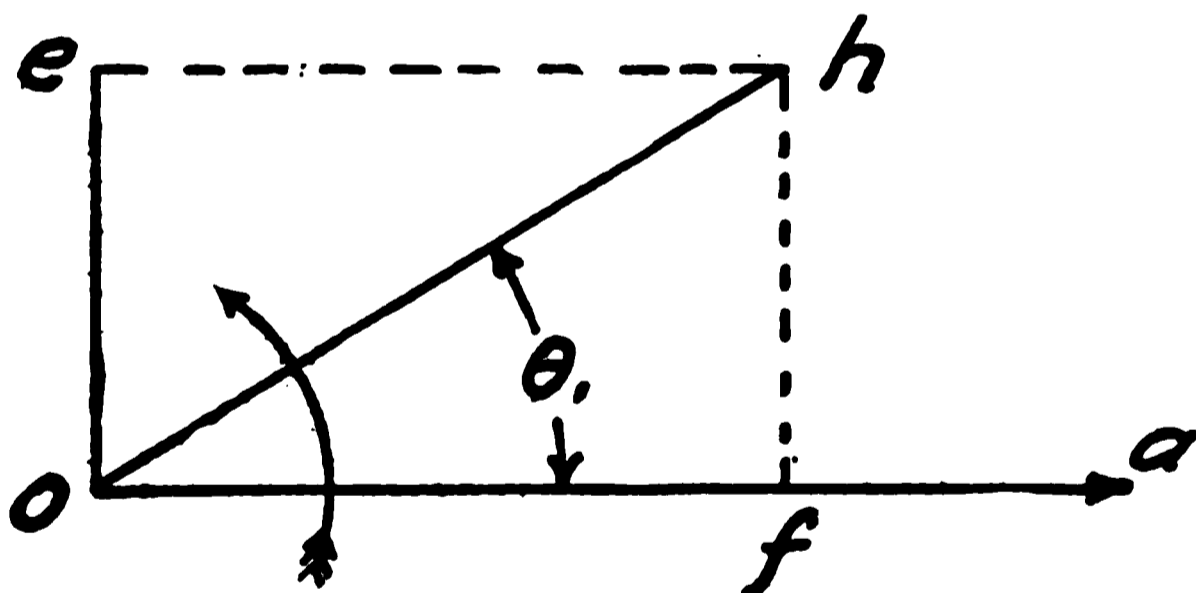


Fig. II

In an alternating current circuit volts \times amperes \times constant = apparent energy = K. V. A.

In a single phase circuit this constant is 1. In a two-phase circuit the constant is 2, and in a three-phase circuit the constant is 1.73.

When the voltage or E. M. F. is constant then current in amperes bears a fixed ratio to K. V. A., so that we may draw

Figures III and IV representing power circuits in which there is respectively inductance and capacity or condenser effect and OB, OD, OE, OH, etc., represent K. V. A. values as follows:

OD or OH = K. V. A. of circuit = apparent energy.

OC or OE = Wattless K. V. A. component.

OB or OF = Energy K. V. A. component = K. W.

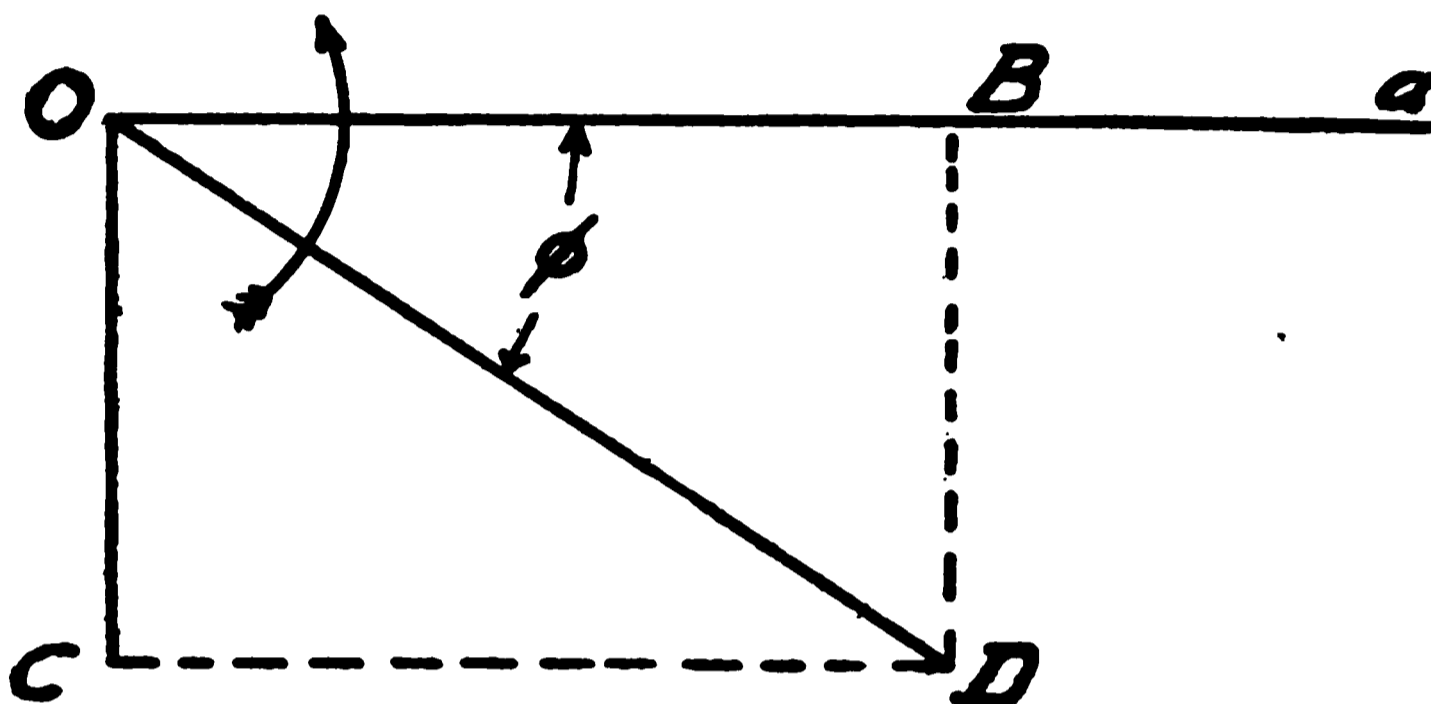


Fig. III

The actual energy flowing in the circuit, Figure III, is OD (apparent energy) \times cosine ϕ . In a case where there is no lagging or leading component OC and OE become zero, angle ϕ or ϕ_1 becomes zero and the power factor is *one*, so that the apparent energy = actual energy, the same as in a direct current circuit.

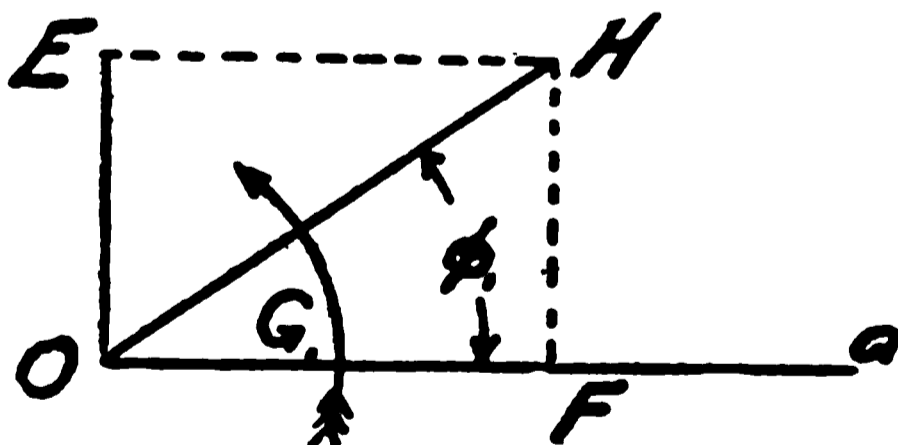


Fig. IV

When a synchronous motor is operating on a line and is over excited beyond the amount required to give the line voltage, it causes a wattless component of current to flow in the line which

is 90° ahead or leading to the impressed E. M. F., having an effect of line capacity or of a condenser.

Referring to Figure IV, a synchronous motor running over excited will take current having a wattless component = OE and an energy component = OG + GF, in which OG = losses in motor and GF = the energy which the motor is delivering to drive its load. When a synchronous motor is run without load then the only energy component is that required to supply the losses in the motor.

The actual current taken by the motor will be the resultant of these two components OE and OF and will have a magnitude and relative phase position OH.

Now, if the current OH is added to the current OD by running the synchronous motor, taking current as shown in Figure IV, on the circuit already loaded as in Figure III, the resulting current on the circuit will have a magnitude and phase position = OL. See Figure V.

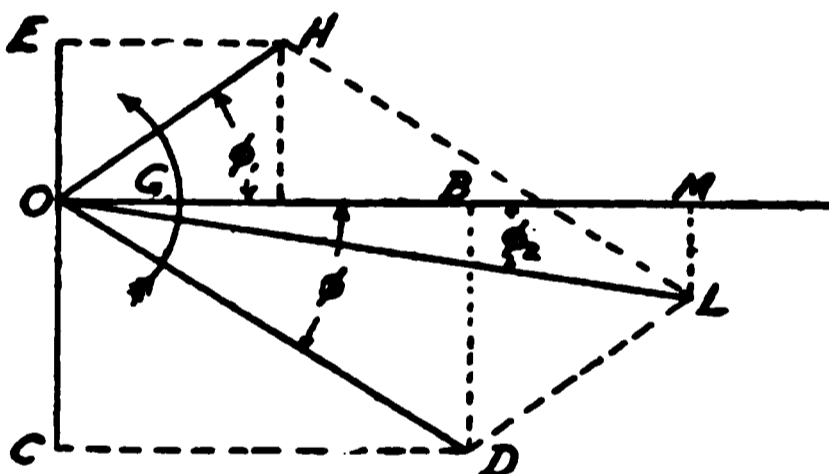


Fig. V

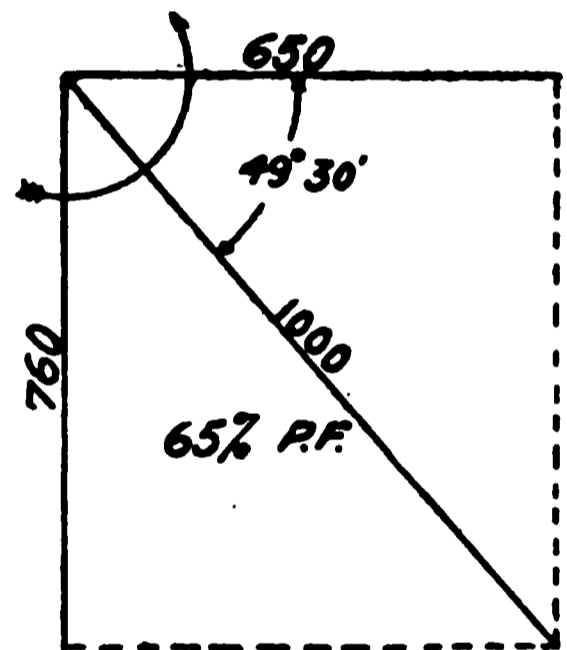


Fig. VI.

The relation of apparent energy OL to actual energy OM is $\frac{OM}{OL} = OL \times \cosine \text{ of angle BOL} = OL \cos \phi_2$. Cosine ϕ_2 = power factor of circuit when synchronous motor is operating and as ϕ_2 is less than ϕ the power factor has been increased or improved.

This improvement of power factor is obtained at the cost of the energy required to supply the losses in the synchronous motor and the investment in the motor. Synchronous motors built for operation over excited at leading currents without load are called rotary condensers.

The following numerical example will illustrate the application of the general case worked out above:

We may assume a station in which the total generating capacity is 1000 K. V. A. continuous, and the load has a power factor of 65.

Then $.65 = \cosine\ of\ 49^{\circ} - 30' = \text{angle of lag.}$

$.65 \times 1000\ \text{K. V. A.} = 650\ \text{K. W. maximum continuous energy load which this station can carry at 65 per cent power factor.}$

$\text{Sine } 49^{\circ} - 30' = .76.$

$.76 \times 1000 = 760\ \text{K. V. A. wattless component.}$

If we now wish to install a synchronous motor or rotary condenser to bring the power factor of this load up to 85 per cent, we proceed as follows:

$.85 = \cosine\ 31^{\circ} - 45' = \text{angle of lag at 85 per cent P. F.}$

$\text{Sine of } 31^{\circ} - 45' = .526.$

$.85 \times 1000 = 850\ \text{K. W. energy load, which the station can carry at 85 per cent P. F.}$

$.526 \times 1000 = 526\ \text{K. V. A. wattless component.}$

The wattless component at 65 per cent P. F. is 234 K. V. A. more than at 85 per cent P. F.

We may now apply the principle described in connection with Figure V, that the wattless component of current, called "leading current," which flows in a synchronous motor or rotary condenser when running "over excited" may be used to neutralize the wattless current produced in a circuit by inductance. The amount of this leading current increases with increase of excitation and a synchronous motor may be operated at no load and at an excitation which will make it take its full load current from the line. This current will all be 90° leading except the energy component required to supply the losses in the motor itself.

In the above numerical example we want 234 leading K. V. A. to raise our power factor from 65 per cent to 85 per cent. We may assume that a 235 K. W. synchronous motor is used, and if run without load the energy loss to drive this machine at full load current leading may be about 12 K. W.

By referring to Figure VIII we see that if the motor operates at no load over excited to take full load current from the line, the current will have a wattless component of more than 234.5

K. V. A., which will give us the result desired in power factor in the station.

This means that in this assumed case where the 1000 K. V. A. generator capacity is only good for 650 K. W. load at 65 per cent P. F. by the addition of a 235 K. V. A. rotary condenser these same generators will be good for $850 - 12$ (the energy required by condenser) = 838 K. W. In addition to increasing the energy capacity of the generators, the exciter voltage required to hold normal voltage on the generators will be very much reduced, thus decreasing the heating in the fields, and therefore improving the efficiency of the generators.

This heating of fields of the generators due to excessive excitation required when running at low power factor means that a given generator, say 1000 K. V. A., will not carry even its full load current at 65 per cent P. F. at the same temperature rise at which it will carry this same current (K. V. A.) at 100 per cent P. F. That is, higher temperature will be obtained by operating the generator at 650 K. W. at 65 per cent P. F. than by operating it at 850 K. W. at 85 per cent P. F. or 1000 K. W. at 100 per cent P. F. The gain in capacity is then actually somewhat more than is shown by the foregoing example. In addition to this the regulation of A. C. generators improves greatly as the P. F. improves.

In the foregoing example the question of obtaining 100 per cent P. F. was not considered because in general this is not practical, for the reason that as you approach 100 per cent P. F. the capacity of rotary condenser required for a stated gain in P. F. increases rapidly.

By referring to Figures VI and VII it will be noted that we increased the power factor from 65 to 85, or 20 per cent, by using 235 K. V. A. rotary condenser. At 85 per cent P. F. there is still a wattless component of 526 K. V. A., which means that it would require about 530 K. V. A. additional capacity of rotary condenser to raise the P. F. 15 per cent more, to 100 per cent P. F.

In the above example it would require

47 K. V. A. rotary condenser capacity to raise P. F. from 65 to 70.

121 K. V. A. rotary condenser capacity to raise P. F. from 70 to 80.

313 K. V. A. rotary condenser capacity to raise P. F. from 80 to 100.

This same result can be obtained by over exciting a synchronous motor that is operating under load on the system. The motor cannot be operated at a current of more than full load current, however, and the proportion of this which is available

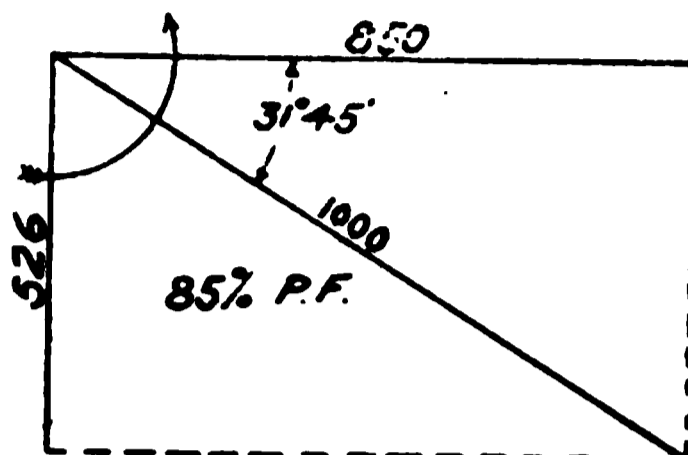


Fig. VII

as wattless current will naturally decrease as the energy component increases. Thus if the 235 K. V. A. synchronous motor were required to carry 150 K. W. load the wattless component of the current would be 181 K. V. A.

$$\text{Thus: } \sqrt{235^2 - 150^2} = 181.$$

If we wish to supply a motor large enough to give 235 K. V. A. wattless leading current and carry at the same time 150 K. W. energy load we would require 279 K. V. A. capacity.

$$\text{Thus: } \sqrt{235^2 + 150^2} = 279.$$

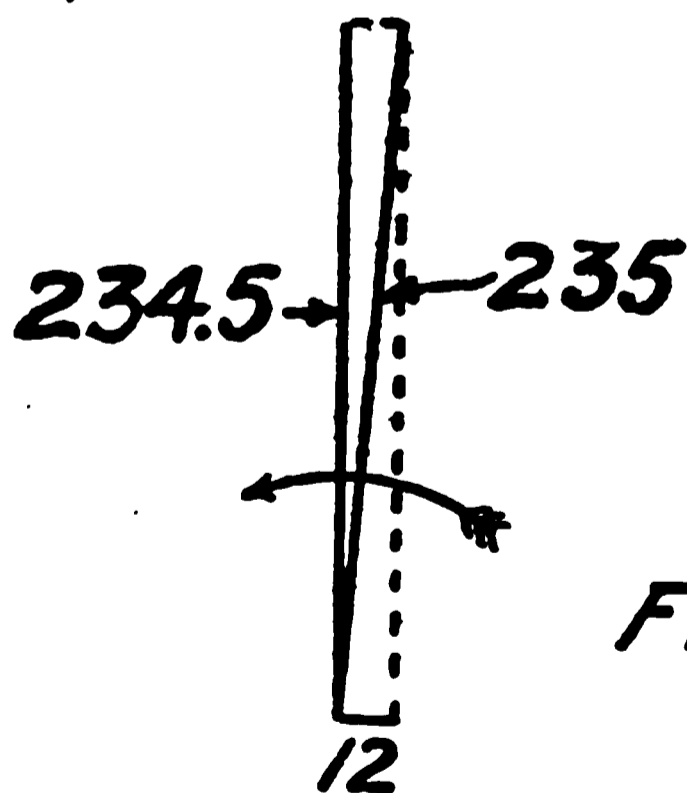


Fig. VIII.

In the last two calculations the losses in the motor are neglected, as their use in the calculations does not change the result any appreciable amount. This is shown in Figure VIII.

The maximum economy of material in building a synchronous motor for both energy output and rotary condenser service is theoretically obtained where the energy component equals the wattless component or both power factor and capacity factor equals 71 per cent, or for angle of lead of current input ahead of impressed E. M. F. of 45° . Standard sizes of machines already developed or existing conditions in a particular case limiting or favoring the utilization of the mechanical power developed by the synchronous motor may make it advisable to depart in one direction or the other from the above theoretical rule.

Actual practice in the use of rotary condensers gives results that are, for all practical purposes, identical with calculated results.

An instance of the installation of a rotary condenser recently installed in the power plant of a textile mill in New England will show how well it accomplished the results it was intended to produce.

The power plant consisted originally of a 600 K. V. A. 100 R. P. M., 600 volt, three-phase, 60-cycle generator direct coupled to reciprocating engine of 780 I. H. P. The engine efficiency was about 92 per cent and the generator efficiency about 93 per cent. This meant that the station was laid out so that the generator could carry a little more than the full output of the engine (498 K. W.) at 85 per cent P. F. = 586 K. V. A. The first motors installed in the mill were 25 H. P. and above having at full load a power factor of 85 per cent and better. Individual motor drive for textile machinery has been adapted almost universally for new installments within the last two years. This means the use of motors varying from $7\frac{1}{2}$ H. P. down to 1 H. P. capacity and therefore a considerable reduction in power factor of the total load. In the case in hand the introduction of a large number of small motors, which were being frequently stopped and started, reduced the average P. F. in this station to 65 per cent. At this P. F. the full capacity of the engine could not be used through the generator. It was proposed to raise the P. F. to 85 per cent by installing a 300 K. V. A. rotary condenser.

A 10 pole, 300 K. V. A., 720 R. P. M., 600 volt self-starting synchronous motor with direct connected exciter and controlling panel, but without shaft extension for pulley, was installed in

power station where regular operators could attend. Below are readings taken showing results actually obtained after condenser was started. A power factor better than 85 per cent is obtained because the load at the time of this test was less than 498 K. W. The readings given are averages of a number of readings taken with each value of current flowing in the condenser. The rotary condenser was of course over excited and the current flowing in it was leading current.

| TEST | | GENERATOR | | | | SYN CONDENSER | |
|------|-------|-----------|-------|--------|-------|---------------|---|
| No. | Volts | Amps. | K.W. | K.V.A. | P. F. | Amp. | Amp.Fld. |
| | | | | | | | No. Syn. Condenser in Cond. floating |
| 1 | 580.0 | 636.3 | 402.0 | 637.4 | 63.06 | | |
| 2 | 578.0 | 611.0 | 406.0 | 611.0 | 66.44 | 0 | 27.5 |
| 3 | 578.7 | 553.7 | 388.2 | 554.1 | 70.06 | 50 | 31.0 |
| 4 | 577.0 | 552.3 | 409.1 | 551.3 | 74.20 | 100 | 35.0 |
| 5 | 577.6 | 524.5 | 409.1 | 524.1 | 78.00 | 150 | 41.0 |
| 6 | 579.1 | 494.8 | 414.5 | 495.6 | 83.63 | 200 | 45.0 |
| 7 | 580.0 | 463.8 | 405.4 | 465.3 | 87.02 | 250 | 50.0 |
| 8 | 580.0 | 452.6 | 412.7 | 454.1 | 90.90 | 300 | 57.0 |

The capacity of this station, without the rotary condenser, with its load at 65 per cent P. F., was nominally 65 per cent of 600 K. V. A. = 390 K. W. By the addition of the condenser the capacity was increased to 498 K. W. full capacity of engine.

498 K. W. at 85 per cent P. F. = 586 K. V. A. (less than 600 K. V. A.) The energy required to operate the rotary condenser at full K. V. A. output leading current is 16 K. W.

The original station, including building foundations, engine, generator, excitors, boilers, switchboard and accessories, cost probably \$110 per rated K. W. installed, or \$66,000 = \$170 per K. W. available at 65 per cent P. F. The price of the 300 K. V. A. rotary condenser installed with panel was \$3,000, increasing the available capacity of the station 108 K. W., which equals a cost of \$28 per K. W., with practically no increase in operating expenses.

The use of rotary condensers in this way is just beginning and it is probable that a great many will be installed within the next year.

In the above case power is utilized in small quantities, so that it was not feasible to arrange to take power from the rotary

condenser. Each individual case, however, requires special consideration.

Another case where a rotary condenser will soon be installed to improve the power factor of a 600 K. W. load contemplates the replacing of a small steam engine now used for driving two 75 K. W. direct current lighting generators by a synchronous motor of 210 K. V. A. capacity, arranged to operate at 71 per cent P. F., this delivering 150 K. W. energy for driving load and 150 K. V. A. leading current, which will be used to raise the P. F. of their total load. This motor will of course be installed in the main station where the other power apparatus is now operating.

Another installation to be made is in a chocolate factory, where the total load on station amounts to 1,500 K. V. A. at 71 per cent P. F. One feeder circuit leading to a center of distribution 700 feet from the generators has 750 K. V. A. load at 71 per cent P. F. The total load, therefore, consists of approximately 1,072 K. W. energy component and 1,072 K. V. A. wattless component. The 750 K. V. A. feeder circuit load consists of 536 K. W. energy component, and 536 K. V. A. wattless component lagging current. A 400 K. V. A. rotary condenser will be installed at the end of the heavy feeder and operated at 400 K. V. A. leading current without load.

This will reduce the current in the feeder to 553 K. V. A. at a P. F. of 97 per cent and reduce the total K. V. A. of the station to approximately 1,225 K. V. A. at 88 per cent P. F.

In conclusion it may be said that in view of the large proportional increase in generator capacity which can be obtained by the use of a rotary condenser in plants where the P. F. is 75 per cent or less and the comparatively small investment per K. W. gain required, there are few plants with a P. F. as low as 75 per cent and in which additional capacity is required, where the use of a rotary condenser is not highly desirable and a good investment. The energy required to supply the losses will be about 5 per cent of total K. V. A. rating of condenser, and although this is not entirely made up by reduction in losses in generators and transmitting conductors it will in most cases prove to be by far the least expensive way of increasing generator capacity available. In addition to this there is always the improvement in generator regulation and in operating conditions, such as reduced exciter capacity and exciter voltage required.

In some cases the latter point alone becomes of sufficient importance to warrant the installation of rotary condenser aside from other considerations.

THE SIX-YEAR ACADEMIC ENGINEERING COURSE.

BY GEORGE R. CHATBURN,

Professor of Applied Mechanics and Machine Design, the University of Nebraska.

One year ago last summer the writer read a paper on "A Combined Cultural and Technical Engineering Course" before the Society for the Promotion of Engineering Education, a national organization which met that year in Cleveland, Ohio.* In this paper was a synopsis of such a course. It was quite favorably received by the society; and later, on a more detailed course along the same lines being presented to our faculty, it was adopted and is now one of the regular courses of the university.

The six-year academic-engineering course makes it possible for a student to fulfill the requirements for the bachelor of arts and also for the technical engineering degrees in six years' time. There is therefore no weakening of either course, but, on the contrary, we think each is made stronger by means of the combination. The writer is further of the opinion that persons not intending to be engineers will find this course to be a very valuable one. The reasons for adopting such course may then be properly placed under two general- and several sub-heads as follows:

I. For the Engineering Student.

1. It gives him a wider knowledge of purely engineering subjects. More subjects are "required," and these are spread over the coordinate branches of engineering, thus allowing the civil engineering student, for example, to become acquainted with those electrical and mechanical engineering topics which, though not strictly civil engineering, may become useful to him in his future career.

2. It gives him a better knowledge of those general cultural subjects, such as language, including the mother tongue, history, economics, and the natural sciences, upon which to build the highest ideal of a technical education.

3. By extending the course easier general subjects will natu-

* Proceedings of the Society for the Promotion of Engineering Education, Vol. XV, 1907, pp. 222-229. Discussion, pp. 239-256.

rally take up much of the time of the earlier years, while the harder technical subjects will be spread over a longer period, thus the mind is better prepared for their reception and will retain them with greater ease. And, unlike requiring a student to complete his academic degree before beginning engineering, he feels that he is working with a purpose in view and that his studies are pointing toward the coveted end, his future profession.

4. It makes him versatile, and versatility is by no means to be despised.

5. Engineering practice in this country is undergoing a change. Heretofore most engineering had to do with the opening and establishment of new industries and in places remote from crowded settlements. The engineer did not come in contact with many of his fellow men and those he did meet were not usually the keenest and brightest. Now he is finding remunerative practice in the larger communities. Employers of his skill are alert, competition is brisk, it behooves him to be most thoroughly prepared.

6. The study of the classics, history, philosophy, etc., is largely of man, while in engineering much pertains to materials and the laws of nature. True, in the upper classes, when the student has reached the highest grade of engineering instruction, that of designing, he may be led to see beyond the design to its purpose, the interest of humanity in it, and thus indirectly gain some of that sort of culture which is obtained through the study of the humanities. But with the crowded curricula and instructors not idealistic the probabilities of his doing so will be small.

7. The argument of the last paragraph indicates the six-year course to be very desirable for that student who wishes to become an engineering teacher.

8. It fits him with the so-called refinements and polish of education. Makes it possible for him to create a good impression by tongue, by pen, by deportment, whether it be before the public, on the rostrum, in society, or in the private and exclusive room of a board of directors.

9. Makes it possible for him to accept promotion in a related branch of his own profession with greater surety of success, or, if circumstances so dictate, to more readily change to a different vocation. In short, makes it possible for him to become a leader

not only in engineering but a man of influence in the general affairs of the community in which he lives.*

II. For the Academic Student.

1. It furnishes a fine preparation for a business career. And this holds true even if only the first four years leading to the bachelor of arts degree be taken. If five years be taken the student would have the scholastic training necessary to fit him for many of those semi-engineering positions such as managers, superintendents and presidents of manufacturing and public service industries. Insurance companies and banks which loan money on buildings often want men of some technical training, while promoters, contractors and salesmen with this same training are always in demand.

2. The earlier years of the course, as outlined, contain some technical work, together with mathematics, thus giving the student an opportunity to ascertain for himself whether or not he has the requisite qualifications for an engineering profession or a business career. If not he can easily branch out into literary or scientific work without detriment or delay. A student who took two years of engineering and then decided to take up agriculture informs me that the careful training in observation, detail and arrangement he received in his engineering work has been of great service to him in his agricultural studies. And this is not an isolated case; all men who have had the engineering training before taking up other lines bear practically the same testimony.

3. The successful man is he who can do as well as dream. The study of engineering subjects especially cultivates those powers and faculties which aid in doing, by creating habits of clear and exact thought, of systematic methods and arrangement. That men shall "be judged according to their works" is indeed true. A man's work makes known to others his peculiar qualities in words so clear, so distinct that "he who runs may read."

4. A training in the application of scientific truth to engineer-

* Professor H. P. Talbot, of the Massachusetts Institute of Technology, in "Science," January 8, 1909, says: "In technical institutions particularly, it is vital to the best results that younger students especially should be made to appreciate that even the grade of professional position which they will ultimately fill will depend upon their ability to view their own profession broadly, upon their ability to take the proper part in community life, and upon their ability to have an avocation which will relieve the tension of uninterrupted and often anxious thought along one line."

ing problems leads to a like application of these truths to the problems of business life.

5. Engineering subjects require a peculiar concentration of mind unknown to most subjects in the academic curriculum; hence there is developed a discipline of the highest order, enabling things to be seen in their right proportion, errors to be detected and evidence to be carefully weighed. The educated engineer is usually "well balanced" and "level headed," seldom "scatter brained"; has that peculiar temperament called "poise," and while judicially conservative is nevertheless progressively radical and resourceful.

6. While the qualities of leadership may not be acquired in the manner of book learning, yet if these qualities are latent in the individual the group method of teaching in use in the best engineering schools will develop, and the very nature of an engineering training, being expository, will aid in their expression.

7. This being an age of invention, an age of great industrial activity, it behooves every man who would have a wide horizon to have some knowledge of engineering. The man who confines himself wholly to language and literature is as lacking in culture as the man who confines himself strictly to technology.

Not long ago I heard Mr. Warner, of the firm of Warner & Swasey, builders of the world's largest telescope, say:

"It is pleasant to find a really big fellow who does not have to talk on his business or his hobby all the time. I went to New York a while ago and in the same car with me were six bankers. I was the only poor mechanic in the whole lot. What do you suppose those bankers talked about till the wee small hours? Nothing but money and stocks. It was a good subject, but there ought to have been a dozen topics on which those men should have been posted, so they would not have to talk shop away from their business."

The outlined course is exactly the same for civil, mechanical and electrical students for the first three years, there being, though, five hours of free electives in the third year. The fourth year shows a small amount of differentiation, the fifth more and the sixth is highly technical. This scheme allows a student three full years in which to "find himself" and decide which one of several lines of engineering he may wish to follow, if any. Likewise those who wish a general course with only sufficient

of the technical to prepare for business will find this a very good selection.

The hours common to the several lines of work are shown in this table:

| | Civil | Electrical | Mechanical | Electives |
|------------------------|-------|------------|------------|-----------|
| Civil | 188 | 131 | 131 | 20 |
| Electrical | 131 | 188 | 141 | 15 |
| Mechanical | 131 | 141 | 188 | 19 |
| Electives (free) | 20 | 15 | 19 | |

The table shows that about four-fifths of all the work is common to the three lines. This is in harmony with the idea that the same basic principles underlie all branches of engineering. Some educators think these are all that it is necessary to teach; that when a college has taught these fundamentals it has taught a man how to go on educating himself after leaving college, and that is as far as any college ought to go. Others think it is the province of a school to teach the "how" of each separate operation of a trade. Our course is a kind of mean between these two extremes.* It should be noted that the other one-fourth is the most technical part of each line.

The six-year course is not peculiar to Nebraska. Michigan has adopted such a course, and Dean Cooley, in a recent letter to the writer, says: "You will perhaps be interested to learn that the indications point to this course becoming a popular one." Minnesota has a five-year course. Harvard requires a baccalaureate degree before entering the engineering courses. Dean Goetze of Columbia says:

"We have been fostering this course to the greatest possible extent for several years. We are strongly advising entering students to come to our engineering courses by way of the college, and there are now some thirty or forty of our students who are taking this combined course. They come into the

* In a toast at a banquet of the Nebraska Schoolmasters' Club, January 8, 1909, Dr. Winship, of Boston, said in substance: "That the schools of today are educating the men of the future, that a man's education should not be so much for a doing of a particular thing as to be such that he might attack and conquer any problem that the future should present. A hundred years ago a hardware store carried in stock but few tools. Today the up-to-date store must have on its shelves hundreds of different varieties. The workman of today needs not so much to be taught the application of a particular tool as to be so educated that when he sees a new tool he can immediately understand its use, and by the general training of his faculties and muscles proceed to use it."

technical school better prepared and more mature and are consequently better able to keep up with the hard work which is required of them in our engineering courses."

Case School of Applied Science, according to President Howe, has an arrangement with Adelbert College whereby their students have the advantage of the combined course. He says, "We had nine men last year and fifteen are coming next year." The Iowa State College, the Massachusetts Institute of Technology and other institutions are considering the same matter.

There are many qualities desirable, if not absolutely essential, to the successful engineer which are inherent, no school can supply them. But a good course of instruction will accentuate the good qualities necessary, and an earnest desire and endeavor on the part of the student will do much to cultivate and make them prominent in his character. Good judgment is the result of experience backed by hard study. Right judgment comes from honesty of purpose. Love of literature and an appreciation of the beautiful are things every engineer should strive for, while agreeable manners and tact are essential to all business success.

THE HISTORY OF A STEAM PIPE.

BY PHILIP K. SLAYMAKER,

Assistant Professor of Applied Mechanics and Machine Design.

Up in the northern part of Michigan, Wisconsin and Minnesota, in what is known as the Ore Ranges, there is being mined, both from open pits and by means of shafts, what appears to be a dark red clay, which is then loaded for shipment. This red clay is iron ore and the region mentioned one of the richest in the world. The ore from this Lake Superior region is known as red hematite and is in fact a natural iron rust, the composition being Fe_2O_3 and containing 70 per cent of iron. The ore after being mined is transported by water to Chicago, Cleveland, Buffalo and other lake ports where blast furnaces are located, or else by rail to inland manufacturing centers, such as that of the Pittsburg district.

The reduction of the iron ore in the blast furnace consists in taking away the combined oxygen and earthy impurities, leaving the pure iron. The blast furnace, which might be designated as a huge gas producer, is a stack usually about 100 feet high, made from steel plates and lined with fire brick. Iron ore, coke and limestone in the proper proportions are charged in at the top and air is supplied as a hot blast through tuyers near the bottom. The air as it enters through the tuyers and starts on its upward journey through the stock in the furnace, unites with the glowing coke to form CO_2 , which is immediately changed by its contact with other pieces of incandescent coke to CO . The final result of this combustion is the formation of CO , entirely free from CO_2 , which constantly rises through the stock. In the meantime the iron ore charged in at the top of the furnace is at once partially reduced by its contact with CO from Fe_2O_3 to Fe_3O_4 , the reaction increasing as the ore descends and meets with higher temperatures. At a depth of 10 feet, where the temperature is about 450°C ., all the Fe_2O_3 is reduced to Fe_3O_4 . The hottest part of the furnace is in the neighborhood of the tuyers and is about $1,500^\circ \text{C}$. While these reactions are going on carbon has begun to be deposited in the pores of the iron ore, and this carbon remaining associated with

the iron furnishes the needed proportion for its conversion into pig iron. At a depth of $13\frac{1}{2}$ feet and a temperature of 500° C., Fe_3O_4 is being strongly acted upon and further reduced to FeO . The limestone coming down with the stock upon reaching a depth of 32 feet and a temperature of 800° C. (at which point all the FeO is reduced to spongy iron) is decomposed; CO_2 is driven off and the caustic lime CaO descends to the zone of fusion to flux the silicious ingredients of the charge. The iron gradually accumulates on the hearth of the furnace and is tapped off at regular intervals. The slag being lighter than the iron, floats on top of it and is drawn off at a point higher up. The iron thus tapped off is run into long, narrow, open sand moulds, and when cool it is called pigs, hence the term pig iron. The gas taken from the top of the furnace varies widely in composition, but a normal gas will have in volume 11.97 CO_2 , 26.42 CO , 1.50 H , .30 O and 59.81 N . This gas is utilized by burning it in the hot blast stoves for heating the air blast for the furnace, burning it under steam boilers for generating power and in some of the more modern blast furnace plants is used directly in gas engines.

The steel from which pipe is made is usually of the Bessemer process because of the easy control and continuous supply of low carbon steel from a Bessemer plant in connection with a pipe mill. The fact that this steel is somewhat higher in phosphorus and sulphur than that of the open hearth process is no objection in welded pipe where the quantity of metal is so greatly in excess of what strength requires, and it also makes the pipe more easily threaded. A small proportion of pipe steel is however still made by the basic open-hearth process.

In the Bessemer process of making steel the pig iron is remelted in an ordinary cupola, and this is sometimes mixed with the molten iron direct from the blast furnace in a large, hot-metal reservoir, from which it is poured into large ladles and then emptied into the converter.

The converter is a large vessel in outline much resembling an egg and made from steel plates. The lining generally used in America is of ordinary silicious rock and clay, and it is from the nature of this lining that the making of steel in such a converter is described as the acid process. By this method phosphorus and sulphur cannot be removed from the charge, and as no steel is allowed to contain more than one-tenth of one

per cent of either, it follows that the pig iron used must not contain more than the allowed amount. The converter is supported by trunnions near its center, thus making it possible to swing it at any angle in the vertical plane. The bottom, which is at the large end, is removable and fitted with nozzles, each of which is cylindrical in form and contains a large number of small holes. These nozzles almost entirely cover the bottom of the converter and open into a wind box which is connected with an air blast through one of the trunnions of the vessel. The converter is first revolved into a horizontal plane, its motion being derived from a hydraulic cylinder, and while in this position receives the charge, which may be from ten to twenty tons of molten pig iron. The blast is now turned on and the vessel turned at once to an upright or an inclined position. The air which is now blowing through the iron burns out the carbon and the silicon, while the process of combustion greatly increases the temperature of the charge. In the making of soft steel the blowing is continued until the carbon is reduced to .05 per cent, which usually requires from seven to twelve minutes, the blower being guided by the change in the color of the flame. The converter is now returned to the horizontal position, the blast is shut off and the metal poured into another ladle. In order that the steel may be tough while hot and able to stand the distortion due to the process of rolling a certain amount of manganese is added while the charge is being poured from the converter. In the case of soft steel this manganese is usually added in the form of a rich alloy called ferromanganese, which contains about 80 per cent of manganese, and this carries with it sufficient carbon to bring the percentage of this element up to the proper amount.

The open-hearth process is a more deliberate one. Pig iron and scrap steel being charged into a regenerative furnace which, as the name of the process implies, has a large, open hearth exposed to the flame, and the charge in this manner comes in contact with the burning gases.

The steel, after being poured into the ladle, whether from the converter or tapped from an open-hearth furnace, is cast into ingots. The ladle has an opening in the bottom for drawing off the steel and in this manner the cinder, which is lighter than the metal and floats on top of it, is prevented from being poured into the mould. The ingot moulds are hollow frustrums of

square pyramids, with the sides inclined only slightly. These moulds have very thick walls, but no bottoms, and are stood on heavy cast iron plates which are carried on small cars. The top of the mould has a cylindrical opening on which a cap is securely fastened after the steel is poured in it from the ladle. After the mould is filled a hydraulic cylinder of a definite stroke moves the car far enough to bring the next mould under the tapping hole of the ladle, and this continued until the entire charge is emptied. The moulds are now taken to the stripper and when the steel has chilled sufficiently the moulds are pulled off leaving the red-hot ingots standing on the cars. As the ingots cool the process of course begins at the outside and as a thick, hard crust will now cover a soft interior it is not in condition to roll, but must be of uniform temperature throughout. To accomplish this the ingot is next put in what is called the soaking pit or pit furnace. Here it is left to soak, as it were, utilizing its own initial heat and being aided by that of the furnace till it comes to the proper condition for rolling, when it is lifted from the soaking pit by an electric traveling crane and then placed upon the mill table.

The table is a roller conveyor which carries the ingot up to the mill through whose powerful rolls it is passed. Back and forth it goes in the process of rolling, and meanwhile is turned over and over so as to roll it on all sides, or skidded from one pass to another by the hydraulic manipulator as if the ingot was a mere plaything instead of several tons of steel. After each pass the cross section is reduced in size and the piece drawn out longer and longer. At last after becoming a section of about 2 inches by 14 inches and after passing through the shear, where it is cut into short lengths, the ingot has changed its name to slabs; the whole operation of rolling consuming about five minutes and the shearing requiring about the same length of time. The slabs are now taken to the plate mill, reheated and again rolled this time into long, thin sheets called skelp, the thickness and width of which depend upon the size of the pipe to be made.

In the process of making lap-welded tubes the skelp is reheated in what is called the bending furnace. This is a regenerative furnace with a hearth long enough to accommodate the skelp for the greatest length of pipe to be made, and of such width as to allow several plates side by side. The furnace opens

in both the back and front, the skelp being charged at one end and removed from the other. When a plate has been heated to the proper temperature it is pushed through from the back of the furnace into the scarfing rolls which prepare its edges for the weld. After passing through these rolls it is pulled through a bell-mouthed casting, called the bending box, by means of a pair of tongs attached to an endless chain which runs over sprocket wheels placed in line with the box. This bell-mouthed casting terminates in a cylinder of a diameter somewhat greater than that of the pipe to be made and the plate is thus bent into cylindrical form ready to be welded. As soon as the bending operation is completed the tongs are released, and the now roughly-formed tube is mechanically lifted from the bending bench and allowed to roll down a set of skids until it falls into a roller conveyor at the back of the welding furnace. In the case of butt-weld pipe the skelp is pulled through a bell-shaped casting, which bends and welds the tube at one operation. The skelp for the large-sized lap-weld pipe is bent by the means of bending rolls instead of using the bending bench as described.

After the pipe has thus been roughly formed it is again heated to a welding temperature, and again pushed through the furnace, but this time into the welding rolls. The welding rolls are about three feet in diameter with their axes horizontal, the one above the other. The bearings are supported in heavy housings, with a screw-down mechanism to secure the desired pressure for welding the pipe. The pass between the rolls is circular, with a diameter a little greater than that of a finished pipe. A cast-iron ball, as it is called, which is rather a pointed cylinder very similar to a projectile, is held central with the pass between the rolls and is less than the diameter of the pass by an amount equal to the thickness of the skelp all around. This ball is held in position on the end of a long bar, the latter being supported at the other end by a machine called the bar puller. As the skelp comes between the welding rolls the edges are thus pressed firmly together against the ball and the welded joint is formed. In special cases, such as boiler tubes, the pipe may pass through the welding furnace and rolls a second time, which is called the second run. In some mills two pairs of welding rolls are placed in tandem. As the pipe is welded it is of course carried on to the bar that supports the ball, so as soon as the

process is completed the bar is withdrawn by the bar puller, the ball dropping into a receptacle in front of the furnace, while the pipe falls on another set of skids and rolls down into another roller conveyor which carries it up and into the sizing rolls.

The sizing rolls are much similar to the welding rolls, but of somewhat smaller diameter, and the whole machine is lighter in construction, and they are not provided with the ball which is so necessary to the process of welding. The purpose of these rolls, as the name implies, is to give the tube the proper size. The operations relative to the manufacture are now nearly completed, the next and final being that of the finishing rolls or, as more generally known, the cross rolls.

These rolls are in form hyperboloids of revolution, placed with their axes crossing each other. The angle made by the projection of their axes and the distance between the rolls themselves varies with the size of the pipe and may be adjusted within certain limits. The pipe enters the cross rolls immediately after leaving the sizing rolls, being still at a red heat, and the combined rolling and sliding action of these rolls makes it spin around very rapidly and at the same time moves it forward at a considerable slower rate of speed. Coming from these rolls, we find the tube to be perfectly smooth and round and it is now automatically lifted on to a cooling rack which conveys it slowly away from the mill. By the time the pipe reaches the end of the conveyor it has cooled sufficiently, whence it is dropped off on a truck and hauled away. The ragged ends are now cut off and the pipe threaded; it is then ready for the market.

The socket or coupling is roughly formed and then welded under a small steam hammer, although there are in many mills machines that perform both operations of bending and welding. The threading of the socket is performed with a special tap so as to give it the taper required to make a tight joint when screwed on the pipe. An older method which is still in use is to tap the socket with a straight tap, but a little small for the pipe, and then expand the ends. Before leaving the mill each pipe is tested by hydraulic pressure, to be sure of a perfect weld.

DOES THE ROTARY STEAM ENGINE PAY?

BY GEORGE S. WILSON, '06.

In the ordinary steam engine the energy in the steam is used to give a reciprocating motion to the piston. This reciprocating motion of the piston is converted into the rotary motion of the engine shaft through the medium of piston-rod, cross-head, connecting-rod and crank. If we should use the energy of the steam directly to produce rotation, we should have the piston

2

revolving about an axis which would be the axis of the engine shaft. We would have a rotary engine, and by this one step would do away with all the intermediate connections, with their attendant friction loss and cost of maintenance.

Examining the patent office records, we find about 18,000 patents covering the rotary steam engine. At the present time hundreds of men are spending time, energy and money in an

endeavor to create a practical engine of this type. In February of 1907 a rotary engine was sent to the Mechanical Engineering Laboratory at the University of Washington, for a steam consumption test. The accompanying drawing is a view of the engine with the cylinder-head removed from the high-pressure cylinders and will illustrate the principle of operation.

When steam is admitted through the steam pipe it exerts a pressure on surfaces E. The pressure on the surfaces F and H is the same. The pressure on surface C is atmospheric. We now have an unbalanced pressure, which is equal to the steam-pipe pressure less atmospheric pressure, acting in the direction of the arrows. If we have a continuous steam supply we will have a constant effort producing rotation of the shaft in the direction as indicated. The pipes B lead to the top of the low-pressure cylinders, where we have an action simliar to the one described above.

It will be noted that the high pressure cylinders have two exhausts; a preliminary exhaust into the low-pressure cylinders and a final exhaust to the atmosphere. The low-pressure cylinders have only the one to the atmosphere. The pistons are kept in their correct relative postions by means of gears on the piston shafts outside the cylinders.

As delivered at the laboratory this engine represented an outlay of about \$1,200. Here are the claims of the inventor: No valves; no dead-points; no vibration; compactness; by the addition of the low-pressure cylinders the steam is used expansively. The engine should develop about 30 brake horsepower and the steam consumption should compare favorably with the best Corliss engine results.

STEAM CONSUMPTION TESTS.

| | |
|--|---------------|
| Duration of tests..... | 1 hour |
| Diameter of cylinders..... | 7.5 inches |
| Distance between centers of pistons..... | 12 inches |
| Length of high-pressure cylinders..... | 4 inches |
| Length of low-pressure cylinders..... | 8 inches |
| Throttling governor. | |
| Alden absorption dynamometer. | |
| Length of brake arm..... | 17.375 inches |
| Weight of brake..... | 8 pounds |

| Test number | 1 | 2 | 3 |
|---|--------|--------|-------|
| Gauge pressures: | | | |
| Steam pipe | 90.0 | 95.0 | 95.0 |
| High pressure cylinders..... | 80.0 | 55.0 | 6.0 |
| Low pressure cylinders..... | 25.0 | 11.0 | 0.0 |
| Exhaust | 0.0 | 0.0 | 0.0 |
| Wet steam (pounds)..... | 1272.0 | 1030.0 | 300.0 |
| Quality of steam..... | 0.99 | 0.97 | 1.00 |
| Dry steam (pounds)..... | 1259.0 | 999.0 | 300.0 |
| Revolutions per minute..... | 950.0 | 758.0 | 758.0 |
| Gross load on scales (pounds)... | 50.0 | 53.0 | 0.0 |
| Net load on scales (pounds)..... | 42.0 | 45.0 | 0.0 |
| Brake horse-power | 11.0 | 9.4 | 0.0 |
| Dry steam consumed per brake horse-power per hour..... | 114.5 | 106.1 | 0.0 |

In an endeavor to locate the cause of this large steam consumption the following tests were run:

LEAKAGE TESTS.

Duration of tests.....1 hour
Engine locked in position. (The position of the rotating parts was changed from time to time so that the results obtained would be a fair measure of the leakage under operating conditions.)

| Test number | 2a | 3a |
|---------------------------------|-------|-------|
| Gauge pressures: | | |
| High pressure cylinders..... | 55.0 | 6.0 |
| Exhaust | 0.0 | 0.0 |
| Leakage—wet steam (pounds)..... | 432.0 | 102.0 |
| Quality of steam..... | 0.97 | 1.00 |
| Leakage—Dry steam (pounds)..... | 419.0 | 102.0 |

Comparing tests numbers 2 and 2a it is found that, provided there had been no leakage, the dry steam consumption would have been 61.7 pounds per brake horse-power per hour. In order to more readily compare these results with those given in tests on a reciprocating engine the mechanical efficiency was assumed to be 65 per cent.

It will be noted that the design of this engine was such that the live steam could not be prevented from blowing into the bearings. On comparing the results of the several tests and observing the actual operation of the engine this was considered

a fair value. The probable indicated horse-power is 9.4, divided by 0.65, or 14.46. The probable dry steam consumption per indicated horse-power per hour is (provided there is no leakage) 40.4 pounds. Under actual running conditions the probable dry steam consumption per indicated horse-power per hour is 69.08 pounds.

Having noted the actual performance of the engine as shown in the tests, let us now take up the inventor's claims in the order of statement and see if they still hold good. The first two claims are allowed, since they are self-evident from the construction of the engine. The third claim is disputed from the fact that the operation of the engine itself disclosed the fact that there was a considerable amount of vibration and also a continuous noise which proved to be very annoying. By a proper design and a careful balancing of the pistons the vibration might be reduced but we should hardly expect from the shape of the pistons and the use of gears at this speed that the noise could be reduced very much.

The next claim of the inventor was the compactness of the engine. Let us see what we have:

The rotary engine occupies 7 square feet of floor space. Square feet of floor space required per brake horse-power is 7 divided by 9.4, or 0.74. Weight of rotary engine is 750 pounds. Weight per brake horse-power is 750 divided by 9.4, or 80 pounds. Height of rotary engine is about 2 feet.

In our laboratory we have a steam turbine which has actually developed more than 7 brake horse-power under test. The steam turbine occupies 3.5 square feet of floor space. Square feet of floor space required per brake horse-power is 3.5 divided by 7, or 0.50. Weight of steam turbine is 375 pounds. Weight per brake horse-power is 375 divided by 7, or 53.6 pounds. Height of steam turbine is about 2 feet.

Taking into account these results we will have to dispute the fourth claim.

The fifth claim is that the low-pressure cylinders use steam expansively.

If we turn back to our drawing it will be noted that if the steam in the high-pressure cylinders is exhausted directly into the atmosphere the pressure when the exhaust opens would be the same as the pressure in the steam pipe. By adding the low-pressure cylinders and the pipes B this is what we actually do:

We have one volume filled with steam at a certain pressure. Suppose this pressure is 70 pounds absolute. We suddenly increase this volume by adding two volumes in which the pressure is, say, 20 pounds absolute. The result is that the pressure suddenly drops to 36.7 pounds absolute. We would now have a pressure of 36.7 less 14.7 or 22 pounds acting to produce rotation in the low-pressure cylinders. It is true then that we have gained some power by the use of the low-pressure cylinders and have produced an effect similar to that obtained by the use of steam expansively; but if we had a true expansion we should have an initial pressure of 70 pounds absolute in the low-pressure cylinders, which would gradually decrease to 36.7 pounds absolute. It will be noted that the turning effort in this case would be considerably in excess of that actually brought about by the action of the engine. The results of the tests will dispose of the claims in regards to the horse-power and steam consumption.

It will be noted that in all these comparisons the data as obtained in the second test is used, while the first test actually shows a greater brake horse-power. This may be explained from the fact that it was found to be nearly impossible to keep the engine in operation for an hour under the load and at the speed used in the first test. The first difficulty arose from the fact that the packing rings (marked A in the drawing) allowed steam to leak past them and so get into the bearings. All available lubricants were used, but still the bearings would not run cool. Finally, after working about a day, we succeeded in keeping the engine running by supplying a constant stream of oil to the bearings and allowing water to flow over their outside surface. Just about this time one of the packing strips (marked S in the drawing) broke. The engine acted as if it were going to pieces. It was shut down at once and a half a day was spent in making repairs. Under these trying difficulties the first test was run. We then decided that it would be absolutely impossible to operate the engine under these conditions, so the speed of the engine was cut down to about 760 r. p. m. The other tests were run at this speed and, while the difficulties were not entirely eliminated, it was thought that it might be possible to operate the engine at this speed.

From the foregoing it will be seen that the main difficulties were excessive steam leakage and excessive heating of bearings.

By a proper design this latter difficulty could be entirely overcome, so that we will only consider the question of leakage.

Going back to our drawing, we will see that the end of each piston carries a packing ring A and three packing strips K. The distance passed over by any particle on this ring or strip increases as its distance from the center of the shaft increases. This means that even if it were possible to prevent leakage when the parts of the engine were new it would be only a question of a very short time before this unequal wear would allow a leakage of the steam past the ends of the pistons and into the exhaust. It is also to be noted that we may have a leakage past the strips S and a leakage between the pistons and in the exhaust.

Another drawback against the use of this particular type of engine would be the fact that the great amount of bearing surface in the cylinders would require an excessive amount of oil for their proper lubrication.

It is not to be assumed that this particular type of engine represents the most economical type of rotary engine, but it serves to bring out the great practical defect of them all, *i. e.*, inability to keep the steam leakage within normal limits.

In our laboratory we have a Ball engine available for test purposes. In order to give us a means of comparison the following test results are given:

| | |
|---------------------------------------|-------------------------|
| Duration of test..... | 1 hour |
| Shaft governor..... | |
| Size of cylinders..... | 8.5 inches by 10 inches |
| Revolutions per minute..... | 283.0 |
| Gauge pressures: | |
| Steam pipe | 77.9 |
| Exhaust | 0.0 |
| Quality of steam..... | 0.97 |
| Indicated horse-power | 33.2 |
| Brake horse-power | 28.4 |
| Mechanical efficiency (per cent)..... | 85.8 |

STEAM CONSUMPTION.

| | |
|--|--------------|
| Wet steam per indicated horse-power per hour.... | 36.08 pounds |
| Dry steam per indicated horse-power per hour.... | 35.00 pounds |
| Wet steam per brake horse-power per hour..... | 42.05 pounds |
| Dry steam per brake horse-power per hour..... | 40.77 pounds |

Having the results of these tests before us, we may bring the question down to one of dollars and cents.

Under the operating conditions in our power plant the cost of overseeing and attendance would be the same in both cases, so that we will only consider the cost of fuel.

Repeated tests on our boilers show that the average cost of coal for evaporating 1,000 pounds of water, from feed water at 32 degrees into steam at 212 degrees Fahrenheit is 25 cents.

On this basis 1,000 B. t. u.'s represent a cost of 0.025 divided by 1.1466, or 0.0218 cents.

The following calculations show the method of obtaining the cost of fuel per brake horse-power per hour in the rotary engine.

Steam at 55 pounds gauge pressure and 97 per cent dry contains 1,147 B. t. u.'s. Total B. t. u.'s furnished to the engine per hour is 1,030 times 1,147, or 1,181,410. Total cost of fuel per hour is 1,181.41 times 0.0218, or 25.75 cents. Cost of fuel per brake horse-power per hour is 25.75 divided by 9.4, or 2.74 cents. Cost of fuel per indicated horse-power per hour is 2.74 times 0.65, or 1.78 cents. Continuing our calculations and expressing the results in tabular form, the cost of fuel in cents is as follows:

Under actual operating conditions.

Rotary engine:

| | |
|---|------|
| Per indicated horse-power per hour..... | 1.78 |
| Per brake horse-power per hour..... | 2.74 |

Reciprocating engine:

| | |
|---|------|
| Per indicated horse-power per hour..... | 0.91 |
| Per brake horse-power per hour..... | 1.06 |
| Provided there had been no leakage. | |

Rotary engine:

| | |
|---|------|
| Per indicated horse-power per hour..... | 1.03 |
| Per brake horse-power per hour..... | 1.59 |

In order to bring out this question of cost still more forcibly, let us continue the investigation one step further.

Suppose we had a plant in which we carried a constant load of 200 brake horse-power for 10 hours a day and 300 days in the year, and that both classes of engines would have the same steam consumption as that given in the tests.

The cost of fuel for operating the plant would be:

| | |
|----------------------------|------------|
| Reciprocating engine | \$6,360.00 |
| Rotary engine | 16,440.00 |

This may be divided as follows:

Reciprocating engine:

| | |
|-------------------------------------|----------|
| Provided there was no friction..... | 5,460.00 |
| Friction cost | 900.00 |

Rotary engine:

| | |
|--|----------|
| Provided there was no friction or leakage..... | 6,180.00 |
| Friction cost | 3,360.00 |
| Leakage cost | 6,900.00 |

SPECIFIC REFLECTING POWER OF SURFACES.*

BY O. R. MALLAT, '07.

The object of the investigation from which the following data were derived was a determination of the candle power delivered at various angles, by a reflecting surface of definite area illuminated by light received from a direction normal to this surface. Professor Morse has suggested the term "specific reflectivity" to be used in this connection.

In general the means employed were the illumination of a surface such as might be used for interiors in building construction or decorations. The dimensions of the surface under test were approximately four by five inches. The lamp used to illuminate the surface, being of the metallized filament variety, was placed at a distance of 1.25 feet from the tested surface and as nearly as possible in a line at right angles thereto and passing through the center. It was necessary, however, to deflect the source of illumination a little below the desired position, in order that it might be suitably screened from the spot-box of the photometer and still permit the reflected light from the surface under test to pass over it into the photometer spot-box.

The relation between the source of light and the illuminated surface was rigidly maintained, both being mounted on the same frame, which was arranged to be rotated through a horizontal angle, about a vertical axis passes through the center of the surface under test. This surface, R, was inclined toward the source of illumination, G, sufficiently to place the spot-box in the vertical angle of direct reflection when the horizontal angle was 0 degrees. (See Fig. 1.)

The photometer used was a Lummer-Brodhun of the Reichsanstalt pattern. A Hall carbon filament lamp was standardized with a standard lamp, so that with a voltage of 81.8 its candle power was 2.47 British units. This intensity had to be made low, because of the low reflecting power of some of the surfaces used. The Gem lamp used to illuminate the surface under test was also standardized, to 51.6 C. P. at 112.8 volts.

* From a thesis prepared by Messrs. O. R. Mallat and C. B. Duer in the Department of Electrical Engineering at the University of Nebraska.

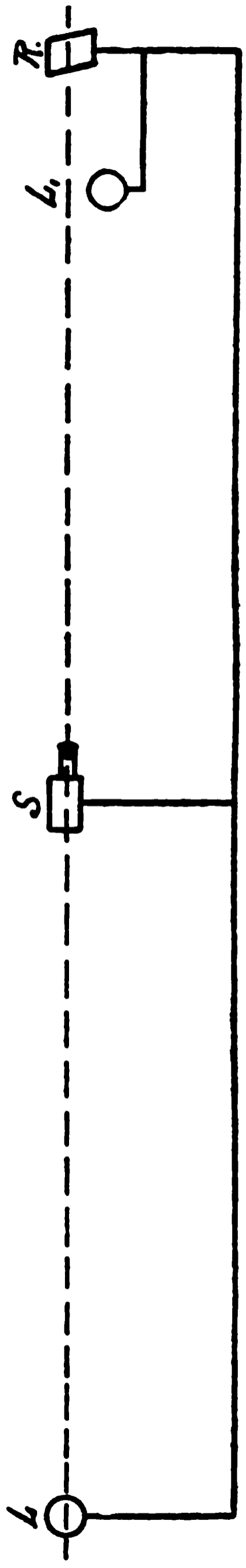
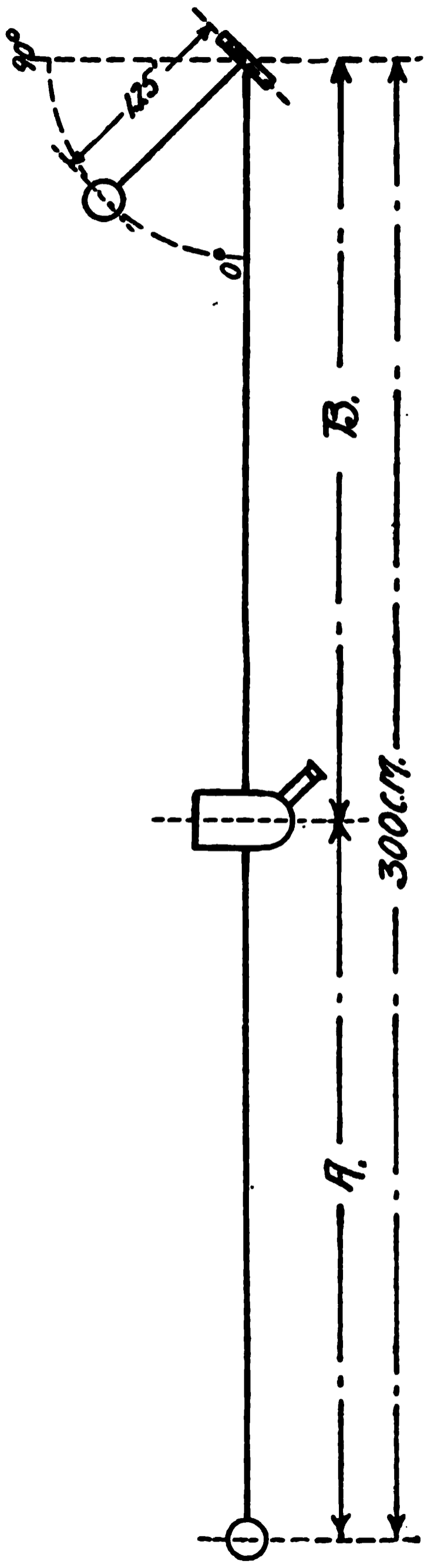


FIG. 1.

o

o

o

o

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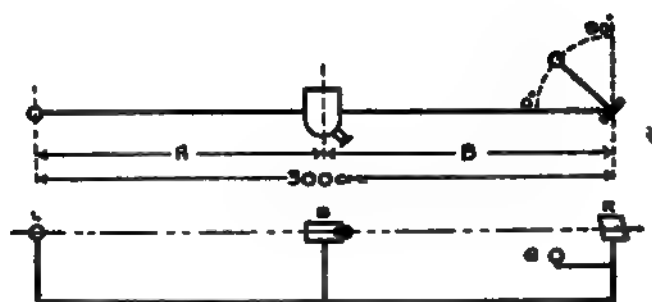


FIG. 2.

Again referring to the figure which shows the arrangement of the apparatus:

L = Standard lamp.

G = Illuminating lamp.

S = Spot-box.

R = Reflecting surface.

A = Distance from standard lamp to spot-box.

B = Distance from illuminated surface to spot-box.

Readings were taken every 10 degrees, from 0 degrees where reflected illumination was a maximum to 90 degrees where it was zero.

The results, as plotted in the accompanying curves, have been reduced to the standard condition of the candle power delivered by one square inch of the illuminated surface under test, illuminated by an intensity of one candle foot, based on the standard British candle. (See Fig. 2.)

As an example of the calculations employed, one observation gave $A = 168$, and $B = 132$, when a balance was obtained between the 2.47 C. P. shed by the standard lamp L, and reflected light received from the surface R. The candle power received from R was accordingly found to be 1.52 C. P. The surface R contained 21 square inches, hence the candle power reflected per square inch $= 1.52 \div 21 = .0724$. The source of light, G, being of 51.6 C. P. intensity, and its distance from R being 1.25 feet, the candle foot illumination on R was $51.6 \div (1.25)^2 = 33$. Therefore the candle power per square inch from the illuminated surface per candle foot of illumination is seen to be $.0724 \div 33$, or .00219 for that particular angular position in which R was placed.

The surfaces tested were:

1. Smooth, white paper with an unglazed surface.
2. Creamy, white typewriter paper.
3. White Damascus bond paper.
4. Dark reddish-brown paper, like pebble finish, except that pebbles are concave.
5. Light yellow paper bordering on lemon, with watered-silk effect, the waterings produced by smooth, shiny surfaces.
6. Plain white surface. Glossy paper with slightly creamish tint.
7. Robin's egg blue paper with small embossed flowers and vines on slightly pebble finish ground.

8. Yellowish orange paper, plain surface, dull finish.
9. Brown paper with suggestion of orange, plain, dull finish.
10. Bright pink paper, plain surface, glossy.
11. Black paper, dull surface embossed with lines like wrinkled surface of an elderly person's hand.
12. Scarlet paper, plain surface, dull finish.
13. Light brown paper, plain surface, glossy finish.
14. Dark scarlet paper, plain surface, glossy finish.
15. Bright, medium-shade green paper, dull surface, embossed, with ground of parallel lines in one direction, with fleur de lis and lines in opposite direction.
16. Dark green linen window shade, painted surface.
17. Cream linen window shade, painted surface.
18. White linen handkerchief.
19. Soft-pine wood, unvarnished, sand-papered smooth.
20. Soft-pine wood, varnished, with three coats of shellac.
21. Olive linen window shade, painted surface.
22. Rough, felted, blue-gray paper, dull surface.
23. Wall paper, light blue, plain dull surface as ground, with brightly reflecting spangles spread over it and figures consisting of chalky-white flowers, with dark blue, thin and curved leaflets.
24. Dark scarlet, felted paper, plain, dull finish.
25. Ceiling paper. Dark cream or light buff, felted, plain, dull surface as ground, with several lines of brightly reflecting spangled surfaces.
26. Dull pink wall paper, felted, plain surface.
27. Wall paper, with very light brown ground, covered with large figures, in which dark blue, black and maroon prevail.
28. Similar to No. 25, except having darker buff or yellowish ground.
29. Very light olive painted linen window shade.
30. Dark olive painted linen window shade.
31. Reddish-brown painted linen window shade.
32. Dark buff or light yellow painted linen window shade.
33. Very dark olive-green painted linen window shade.
34. Medium-shade blue painted linen window shade.
35. Grayish-white painted linen window shade.
36. Dark green painted linen window shade.
37. Drab painted linen window shade.
38. Plaster of Paris, ordinary finish.

- 39. Plaster of Paris, sand-papered.
- 40. Mirror.
- 41. Ground glass, rough side.
- 42. Plain window glass.
- 43. Chipped glass.

The curves exhibit in a marked degree the relative effect of direct and indirect or diffused reflection. At only one position was the photometer screen in the angle of direct reflection, which which the curves show is the axis of symmetry. For strongly reflecting surfaces, such as white paper, yellowish, orange paper, plaster of Paris and a mirror, this position is marked by sharp augmentation of the light delivered by the reflecting surface, as indicated by the pointed effect in the curves referred to.

As the foregoing curves are plotted to different scales, on account of the varying intensities, the relative magnitude of the light reflected from various sources is not easily apparent. The figure on page 71 exhibits curves from white paper (No. 1), scarlet paper (No. 14), green window shade (No. 16), and plain window glass (No. 42), drawn to the same scale and superimposed.

This investigation was suggested through an appreciation of the meaninglessness of any possible co-efficient of diffused reflection, in the absence of knowledge as to the extent of area involved. By reference to the data given it should be possible to treat each elementary strip of an illuminated wall as an original source of light, presuming, of course, that the degree of illumination shed upon it is known.

No. 1.

No. 2.

Scale 1" = $\frac{1}{1000}$ C. P.

Scale 1" = $\frac{1}{1000}$ C. P.

No. 3.

No. 4.


Scale 1" = $\frac{1}{1000}$ C. P.

Scale 1" = $\frac{1}{1000}$ C. P.


*No. 5.**No. 6.*Scale 1" = $\frac{0''}{.0018}$ C. P.Scale 1" = $\frac{0''}{.0018}$ C. P.*No. 7.**No. 8.*Scale 1" = $\frac{0''}{.0009}$ C. P.Scale 1" = $\frac{0''}{.0018}$ C. P.

No. 9


No. 10.



Scale 1" = .00036 C. P.

No. 11.


Scale 1" = .0018 C. P.

No. 12.


Scale 1" = .00018 C. P.


Scale 1" = .00036 C. P.

*No. 13.**No. 14.*

0°
Scale 1" = .0009 C. P.

0°
Scale 1" = .0018 C. P.


*No. 15**No. 16.*


0°
Scale 1" = .00036 C. P.

0°
Scale 1" = .00018 C. P.

No. 17.


No. 18



Scale 1" = .0009 C. P.


Scale 1" = .0009 C. P.

No. 19

No. 20


Scale 1" = .0018 C. P.


Scale 1" = .0018 C. P.

No. 21.

No. 22

,
,

^σ
Scale 1" = .00036 C. P.

^σ
Scale 1" = .00072 C. P.

No. 23

No. 24.

^σ
Scale 1" = .0009 C. P.

^σ
Scale 1" = .00036 C. P.

No. 25.

No. 26.

Scale 1" = .0018 C. P.

Scale 1" = .00072 C. P.

No. 27.

No. 28.

Scale 1" = .00036 C. P.

Scale 1" = .0018 C. P.

No. 29

No. 30

♂
Scale 1" = .0009 C. P.

No. 31.

♂
Scale 1" = .00035 C. P.

No. 32.

♂
Scale 1" = .00036 C. P.

♂
Scale 1" = .0018 C. P.

REFLECTING POWER OF SURFACES.

83

1133

1134

Scale 1" = .00018 C. P.

Scale 1" = .00018 C. P.

1135

1136

Scale 1" = .0018 C. P.

Scale 1" = .00018 C. P.

*No. 37.**No. 38*

Scale 1" = .00036 C. P.

Scale 1" = .0018 C. P.

*No. 39**No. 40*

Scale 1" = .0018 C. P.

Scale 1" = .036 C. P.

*No. 41.**No. 42.*

Scale $1'' = .00036$ C. P.

Scale $1'' = .00036$ C. P.

*No. 43.**No. 44.*

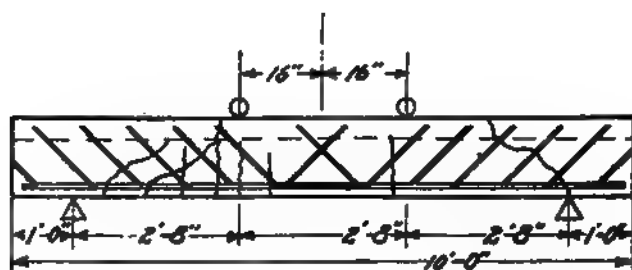
Scale $1'' = .0009$ C. P.

A STUDY OF SHEAR MEMBERS IN REINFORCED CONCRETE BEAMS.*

BY CLARK E. MICKEY, '08, *
Instructor in Applied Mechanics.

The simplest form of reinforced concrete beam construction is one in which the compressive stresses are taken by the concrete and the majority of the tensile stresses by the reinforcing material. This principle, of equalizing the compressive

BEAM No. 9.



Reinforcement.— 2- $\frac{1}{2}$ " Kahn bars, flanges sheared
15" c. to c. Area 1.05" Flange @ 45°

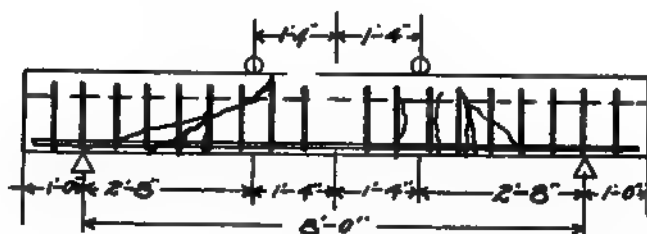
and tensile strength in concrete beams by employing high tensile strength materials in that portion of the beam which is subject to tensile stresses, was used as early as 1871, at which time a house of reinforced concrete was built in Port Chester, N. Y. The real impetus, however, to this new form of construction was given by Mr. Ernest L. Ransome in 1897-8, when he designed

* Part of a thesis by G. A. Crook, C. G. Hrubesky and Clark E. Mickey.

and built two reinforced concrete factory buildings for the Pacific Coast Borax Refinery.

The present knowledge of the behavior of reinforced concrete, when subjected to tests, has led to the adoption of various forms of reinforcements, each having some particular advantage. Any form of construction which employs the steel for tensile and shearing (sometimes called diagonal tension) stresses and the concrete for compressive stresses, if properly designed, will give excellent results in practice.

BEAM N°11



*Reinforcement: - 2-3/4" Kahn bars, flanges sheared
12" c. to c. Area 1.05" Flanges vertical.*

The object of this series of tests was to observe and compare the behavior and results of reinforced concrete beams, when tested to destruction, with two distinct types of shear reinforcements.

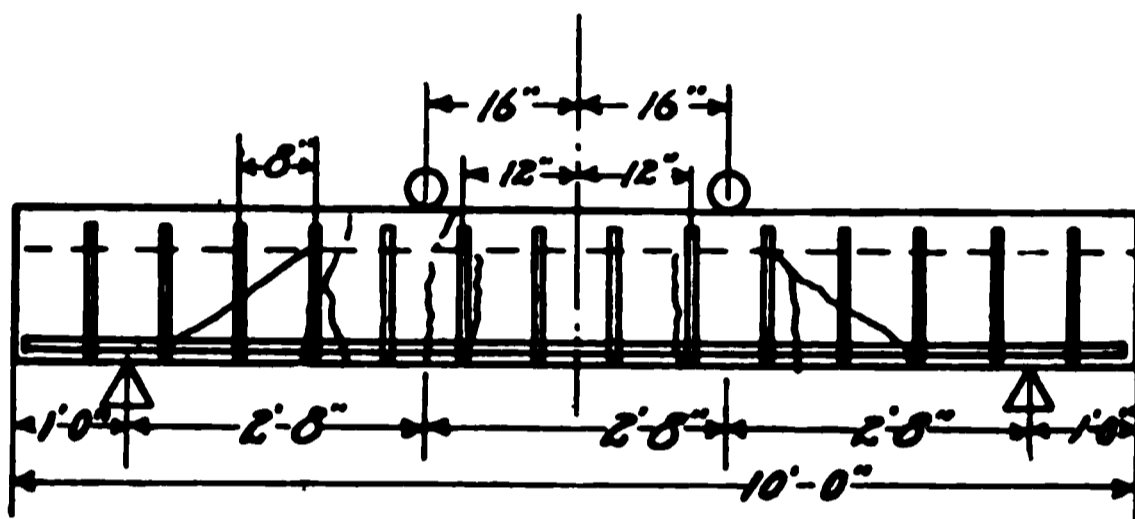
First: Plain tension rods with loose shear members placed vertically and also inclined at 45 degrees from the center.

Second: Similar tension rods with rigidly attached shear members placed vertically and also inclined at 45 degrees from the center.

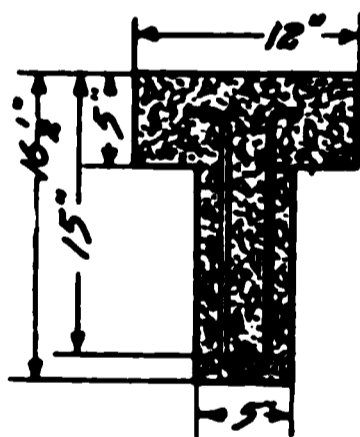
In other words, to determine the difference in results when either loose shear members are used, both in the vertical and inclined positions, or when rigidly attached shear members are used, both in the vertical and inclined positions.

The steel employed was all of the same quality and of the same quantity in the beams to be compared, the only variation being in the type and positions of the shear members. The usual Kahn reinforcing bar was used with the flanges sheared

BEAM N° 3.



*Reinforcement. - 1-1" x 3" Kahn bar, flanges sheared off.
Area 1.0" 14 Stirrups 30" long, spaced 8" cc*



for the rigid shear members and sheared off to furnish material for the loose shear members.

The beams were made in two lengths and two cross sections, as will be noticed from the figures showing the types of reinforcement. They were all moulded and stored out of doors. A level place was prepared by using sand and gravel for ballast, and the forms were then set up over a 1" x 12" piece of lumber. The forms were of dressed white pine and gave very little trouble from undue warping. They were built so that they could easily be removed from the beams and set up for another beam. The concrete was mixed by hand with shovels. All materials were

measured by loose volume and in the proportions of 1 : 2 : 4. The cement and sand were thoroughly mixed before adding the stone, then the whole was mixed, water being added, and the mixture turned until it had uniform consistency. The concrete was wet enough to cause the water to flush to the surface after being well tamped in the forms. A 4" x 4" cube was moulded from the same mixture. The beams were kept wet and protected for the first four or five days and sprinkled every few days after the forms were removed.

The arrangement of the testing apparatus is fully illustrated by the accompanying figure. Two 13-foot x 12-inch I-beams were placed upon the weighing table of a 200,000-pound Riehle testing machine, and directly upon these rested the edges which supported the test beams. All of the test beams were loaded at the one-third points, the load being transferred from the machine by two 80-pound steel rails with a 1½-inch roller above and two 2-inch rollers below. Steel bearing plates of ½ x 3-inch material were used above and below the test beams for the bearing of rollers and supports.

The loads were applied at the slowest speed of the machine, the increase of deflection averaging about .15 inch per minute. The loads were increased by increments of 1,000 pounds and the beams were all tested to destruction in order that the method of failure could be observed and photographed.

The arrangement for observing the deflections was as follows: Two knife-edges 1 inch high were placed on top of the I-beams and vertically over the edges of the weighing table of the testing machine, as these points were points of zero deflection of the I-beams. Upon these knife edges a ½ x 3 x 48-inch steel bar rested and served as the deflectometer support. This was a Reihle instrument and graduated to read accurately to .001 inch. The end deflections of the I-beams, due to load on the test beams, was observed directly under each support by means of a micrometer caliper which read accurately to .001 inch. This instrument was adjusted between fixed points of the I-beams and a nail head in a 4 x 4-inch post rigidly attached to the floor directly under each support. It is obvious at once that the true deflection of the concrete test beam, at the middle of the span, is obtained by subtracting the mean of the two end deflections of the I-beams from the deflection as read from the deflectometer. This true deflection was used for the abscissa in plotting the

ARRANGEMENT OF TESTING APPARATUS

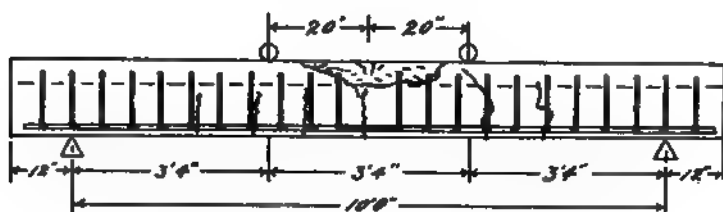
Elevation

*the right
is the
of deflection
is taken, and C is the point of
which the maximum deflection is taken*

ordinary load—deformation diagrams. This novel feature of eliminating the error due to the deflection of the I-beams was very simple and proved to give the very best of satisfaction in all of the tests. No attempt was made to locate changes of position of the neutral axis of the test beams under different loads, as this element was not included in the original outline of the work.

Comparison of results: The table showing the comparison of results has been arranged to illustrate the comparative stiff-

BEAM "B.



*Reinforcement, 2- $\frac{3}{4}$ " Kahn bars, flanges sheared 12" 6.104 of bar
Frangs Vertical-Alternate Shearing.*

ness of the test beams rather than attempt to compare the strengths from the maximum loads observed. In order to accomplish this purpose an elastic line was drawn on the ordinary load-deflection curve. From this line the actual deflection at 15,000 pounds was observed, which appears in the seventh column of the table. The corrected deflection, eighth column, was obtained by moving the origin of the curve until the elastic line would pass through it. The relative deflection, ninth column, was found by multiplying the corrected deflection of the eight-foot span test beams by 1.955 (the ratio of the cubes of the

TABLE I.
Comparison of Results.

28

26

24

22

20

18

16

14

12

10

8

6

0

100

200

300

400

Deflection in inches

two-span lengths) and by recording the corrected deflections for the ten-foot spans, thus reducing all the deflections to the values that would have been observed if the beams were all of ten-foot span lengths.

It will be noticed, by referring to the last column of the table, that all of the deeper beams of small cross-section (Nos. 1, 2, 3 and 4) failed by diagonal shear, which seems to indicate that the reinforcement was not sufficient, especially in the shear members. The majority of the large cross-section beams (Nos. 5, 6, 8, 9 and 11) failed by compression, the failure in beam No. 9 being due to both shearing and crushing. The shearing, however, was its principle failure and, further, this was the only instance where the diagonal shearing and compressive strengths of a beam approached equality. Beams Nos. 9 and 11 were the only ones of this cross-section that exhibited failure by diagonal shear.

General conclusions: Since all of the deeper cross-section beams failed by diagonal shear and both of the 8-foot span lengths of the large cross-section beams failed by the same method, it is evident that the diagonal shearing stress increases directly as the depth and as the length of same is decreased.

Attached and loose shear members: The attached shear members gave the most rigid and strongest beams.

Attached, vertical and inclined: The beams reinforced with the attached inclined gave the best results in each case.

Loose, vertical and inclined: The comparison in this case is very difficult, but in beam No. 6 the inclined members developed the full strength of the concrete in compression. This was probably due more to the length of the span than to any other one element. The hooked ends in beam No. 3 didn't seem to assist the shear members.

Finally the attached inclined members gave the results in every way.

GENERAL FEATURES OF POWER STATION DESIGN.

BY I. E. BROOKE.

The general problem of power station design is controlled in almost every case by local conditions. There are very few instances where a design for one location under a given set of conditions will answer for another location or set of conditions. There is perhaps no station that will permit what might be termed ideal design; local conditions generally impose limitations which cannot be overcome in an ideal manner.

The first problem, of choosing a site, is one that is often not given the proper study, being governed in many cases by a low first cost. This of course is desirable, but in some instances a free site is more expensive than one costing thousands of dollars. In selecting a proper site, if other limiting conditions permit, it is well to choose one as near as possible to the center of gravity of the load, or at least so that the increase in load will tend to bring it nearer this center. At the time of low voltage distribution this point was a very important one, but with the present-day high voltage systems, where the transmission losses are much lower, the advantage of such a location is not so great.

The question of providing for a proper supply of coal and the storing and handling of same should be thoroughly investigated. The removal of ashes is one of the things that is often considered too late. It is generally advisable to have a location such that coal can be brought either by rail or water and the building should be so located that the smallest amount of handling or conveying apparatus is required. In large stations using from 600 to 1,200 tons of coal per day the question of providing sufficient storage for a reasonable length of time is one of utmost importance. Here again the method of handling coal to or from storage should be given careful consideration.

In some of the more recent plants engineers have realized the value of storing coal under water. Tests have shown that when coal is stored in the open it loses from 2 to 10 per cent of its heating value, while in under-water storage this loss is inappreciable. The loss in most cases appears to take place during the

first five months, the percentage loss, of course, depending on the kind of coal, being greatest in coals containing relatively high amounts of volatile combustible matter. After a very thorough investigation of this subject the Western Electric Company provided at their Hawthorne plant two storage bunkers, one of 4,000 and one of 10,000 tons capacity. These bunkers are so constructed that coal can be dumped directly from the car into them and then the entire bunkers flooded with water. An additional point in favor of under-water storage is that spontaneous combustion is effectively taken care of, while coal stored in the open is subject to this undesirable method of burning. This matter of efficiently storing coal will receive more and more attention as the available supply becomes smaller.

Next to the problem of proper coal supply and storage comes the supply of water. A reliable supply of cool water for condensing purposes in a plant of any size is recognized as an absolute necessity, and this point alone may outweigh all others in choosing a station site. Where other conditions will permit, the station should be so located that the cost of pumping condensing water is reduced to a minimum.

Provision must usually be made for keeping out foreign substances, fish or floating debris in the water. This is generally taken care of by having suitable screens at the intake, and these should always be in duplicate, so that one set may be taken out and cleaned while the others remain in service. A supply of good, clean water as free as possible from all solid matter is desirable for boiler feed.

The general design of the building will depend upon local conditions and the value of real estate. If building property is comparatively inexpensive then the plant may be spread out to advantage, but where land is valuable it may prove more economical to build "up," even to the extent of double decking the boilers.

Foundations for building and machinery must be well taken care of, and especially in soft ground or low places test borings should be made to determine the nature of the soil beneath the surface. In localities where a good, firm earth is not obtainable a very satisfactory foundation is often made by driving long piles and capping them with a block of concrete, the piles having been first cut off below the moisture line.

The advantage of having plenty of room around the turbines or engines and boilers is obvious. Wide aisles make it easier

to remove or replace machinery; they facilitate making repairs and permit the station or apparatus to be cleaned in a better manner.

The general arrangement of apparatus should be given careful study in each particular case, as a great deal can usually be accomplished by careful consideration of the general layout, especially when the more important details are kept in mind. The boiler feed pumps are now generally placed in the engine or turbine room, where they can be kept clean and given the proper attention. This leaves the fireman only to handle the fires and boilers and look after the steam pressure. In plants where a large number of boilers are installed they are often set back to back with a wide firing space between. With this arrangement a fireman can handle a large number of boilers with considerably less work.

On account of the cost of maintenance and repairs on the type of conveyors known as the "continuous" or "overlapping bucket" many large plants have installed a so-called "unit" system of ash and coal handling apparatus. This system usually consists of a traveling crane, carrying a grab bucket, and so arranged that the crane bridge travels above the bunkers, while the crane track is extended so that the bucket can pick coal directly out of a car. This system has the advantage that where bottom dump cars are not available that a second crane with grab bucket is not required for unloading from the car.

Where ashes are handled in a continuous bucket conveyor the cost of maintenance is of course much greater. There has recently been developed and put on the market a pneumatic system of ash handling machinery which operates much the same as the ordinary pneumatic tube system. This system has not been in use long enough to get much data on the cost of maintenance, which is the important factor in ash handling equipment.

The capacity of the coal bunkers is determined by the outside storage plant and the facilities for handling from this supply. In some plants of recent design apparatus has been installed for weighing the coal burned under each boiler. In the opinion of the writer it is questionable whether this expense is justifiable, except perhaps in very rare cases. However, some method should be provided for weighing the coal so used, at stated intervals, and careful records should always be kept of the amount of coal burned each day.

The question of selection of boilers is usually one of size rather than type, except perhaps in small plants. The advantages of the water-tube boiler are too well known to be repeated here.

Stokers are generally a good investment where more than four or five boilers are installed, but they are often handled in a way which will not produce the best results. The selection of stokers should be governed by the kind of fuel available. Chain-grate stokers, while having many advantages, do not lend themselves efficiently for a sudden demand for steam. One point that is sometimes overlooked in the installation of stokers is the correct supply of air, as too much air may be as harmful as too little. In some stokers air is admitted only at the front of the grate through an opening, the size of which can be regulated, and if the air spaces in the links are properly designed for the kind of fuel used, this scheme should give satisfactory results.

In steam turbine plants the superheater is considered a necessity as well as an efficient piece of apparatus. The advantage to be gained by the installation of economizers is questionable in most cases, as they affect the draught and may reduce the boiler output at a critical time.

After listening to a lecture in the college class room by a very able engineer on the subject of forced draught, the writer was thoroughly convinced that forced draught was the correct and only thing. After seeing almost all of the large power plants build expensive stacks, the correctness of this opinion is now somewhat questionable.

The question of engines versus turbines is one that has received a great deal of attention and brought out much discussion among engineers within the last few years. For large plants, however, most engineers are willing to concede that the turbine has won the day. The advantages of the steam turbine may be pointed out briefly as follows: the lower first cost, smaller number of moving parts, less weight, requires less space, the absence of internal lubrication, excellent regulation, which means uniform speed and high efficiency at part load. There are also the advantages that the turbine is suitable for a high degree of superheat and that the condensed steam may be returned to the boilers. The latter is a decided advantage, especially where good feed water cannot be secured economically. This advantage has been questioned by some who claim that the pure water thus returned to the boilers would rust them.

It is well known that pure water, containing some free oxygen, will attack iron very rapidly; however, this effect has not been noticed to any great degree, probably because with the high degree of vacuum generally maintained in steam turbine practice most of the air is withdrawn.

The generating apparatus is usually selected from the standpoint of "total efficiency" rather than from a consideration of the efficiency of the machine itself. As generators are now constructed to give a pressure of from 10,000 to 15,000 volts, step-up transformers may be dispensed with for transmission over considerable distances. The load factor has an influence on the selection of equipment which is often not given due consideration. Where large peaks are encountered for a short time in the year or for a short period during the day it may not be advisable to install high efficiency apparatus to handle this part of the load. The increased first cost, giving a large interest charge on the investment, may not balance the loss due to inefficiency for a short period. Under such conditions it will often prove more economical to purchase equipment with a very much larger overload capacity than is usually specified, not aiming at high efficiency for the peak load. This matter of the ratio of interest on investment and depreciation to the operating cost is one that should be given particular consideration in economic station design, especially in stations having a very low load factor. In any plant the losses, so to speak, may be classed as fixed charges, and cost of maintenance and operation, and when these two are equal the total cost per unit output will be the least.

If there is any one thing more than another that is taking the attention of the steam engineer at the present time, that one thing is the exhaust steam turbine. These units can be installed in plants where reciprocating engines are doing good service and by utilizing the exhaust steam from the engines effect a saving of from 50 to 65 per cent, when a high degree of vacuum and suitable condensing apparatus are used.

In the selection of auxiliary apparatus the question of reliability should be paramount, as in the modern turbine stations most of the trouble is experienced with the auxiliary apparatus. The choice of steam or electrically driven auxiliaries depends upon the system of operation to a very great extent. In some plants where steam auxiliaries have been installed it is claimed

that better station economy is secured on account of the exhaust steam being available for heating feed water. The cost of steam-driven auxiliaries is less, but they have the advantage of being independent of the generating equipment and so are more reliable in case of electrical disturbances. In plants where steam-driven auxiliaries are used the degree of superheat is practically determined by the satisfactory lubrication of engine cylinders. This limitation of superheat may result in a lower efficiency in the turbine unit itself, which may outweigh the inefficiency of electrical auxiliaries. The auxiliary apparatus should be installed complete for each unit, but should be interconnected so that they can be used for the adjacent unit if necessary. However, in a large plant containing many units it is unnecessary to have exciter sets, oil pumps, etc., for each unit.

The question of multiple versus independent operation of units and stations is one well worth a lengthy consideration. Central station managers are giving more and more attention to the reliability of service, and so the engineer has to give more study to the problems involved in safety and continuity of operation. In many large power plants the unit system has been adopted throughout. The extent to which this system should be carried depends upon the relative importance of keeping every unit in service. Where there are only two or three units and all are needed for the peak load it is well to provide cross connections, both on the steam and electrical sides, so that one unit could be run from any or all the boilers and all feeders from any or all generators. As the number of units is increased so that any one particular unit is not so large a part of the total installation, this precaution of interconnection may be provided, but to a lesser degree. In fact, cross connections may be dispensed with entirely, making each unit a separate and complete plant in itself. The argument for this type of station is that it is not possible to make a mistake in making cross connections between units which might disable the entire plant. On the other hand, it does not seem economical to shut down a large unit on account of the failure of some minor auxiliary apparatus. There should be a medium between absolute isolation, where the failure of a small part may shut down the entire unit on the one hand and where the wrong manipulation of complex cross connections would shut down the entire plant on the other hand.

A prominent engineer has criticised the building of one very

large power plant in place of two smaller ones. The advantages of one large power plant are: economy of fuel, smaller floor space per kilowatt installed, less first cost and economy of operation. The disadvantage is of course the crippling of an entire system if the other stations cannot carry the overload brought on by disabling one station. Where continuity of service is important and power is generated in large quantities it is generally better to build two separate stations.

In stations where an operating room is necessary, it should be so constructed that the operator has a full view of all apparatus under his care. The room should be enclosed by glass to shut out the noise and also to protect the instruments from escaping steam.

It is not the ideal thing in power station design to make use of the unit system from coal pile to substation, taking every precaution against interruptions and then put the entire plant under one system of control. The Niagara plant was shut down, leaving Buffalo cut off from this source of power for about eighteen hours. The interruption was due to lightning destroying the cables that lead from the generators to the transformer house. However, the points that may be brought up in discussing the question of duplicate controlling systems are not all in favor of a secondary system. If the station is one of a number feeding a large system, a duplicate system of control may not be necessary, but if the station is an important one, where a shut-down would mean a great deal, this additional expense may be more than justified. In case a duplicate system of control is installed it should be put in in such a manner that no wires common to the two systems are necessary. This may be accomplished, in a measure at least, by means of "throw-over" switches. The writer has seen a duplicate system installed as follows: A power station supplied a very important substation by two three-phase, four wire, overhead circuits, these circuits being arranged at the power station end so that in case one wire was grounded or out of service the neutral wire of either circuit could be switched in, in place of this phase wire. This scheme, while theoretically a good one, involved a rather complicated system of switches, and after being installed about four years was called upon to do service, with the result that the operator made a mistake, resulting in a shut-down of the substation. However, such mistakes cannot be held against any

particular system, but the fact that the operator can and does make mistakes must be kept in mind by the designing engineer.

To provide absolute "fool-proof" apparatus or methods of operation is generally beyond the ability of the designer, but in large central stations an attempt is made to have both the apparatus and the operation as near "fool-proof" as possible.

To facilitate operating, bench boards or operating boards have been designed on which are placed signal lamps, oil switches, control switches and "dummy busses." This scheme enables the operator to tell where each generator or feeder is connected and also the position of all oil switches.

In the installation of the electrical apparatus there are a number of points well worth consideration. For moderate voltages, say up to 15,000 volts, the writer is in favor of having all bus bars, switch connections, etc., thoroughly insulated. Care should be taken to ground properly all cable sheaths, transformer cases, switchboard frames and instrument transformer secondaries. One ground wire should be run for lightning arresters or static dischargers, a second wire for instrument transformer secondaries, and a third for cable sheaths and transformer cases.

It has become standard practice in the larger stations to provide two generator switches, so that either of two busses can be selected. In stations where motor-driven exciters are used the installation of a storage battery on the exciter bus is also a common practice. In addition to maintaining a constant pressure on the exciter bus, this battery furnishes a reliable source of current for operating motor-controlled oil switches, circuit breakers, rheostats, field switches, and governor motors. The installation of a transfer bus, so that any feeder can be thrown to one of several generators, is very desirable. The sectionalizing of main busses is generally a good precaution. Generators and feeders should be equipped with overload and reverse current relays. Sufficient mechanical protection and isolation of generator leads, busses, and switch connections should be provided to prevent failure due to short circuits or grounds on adjacent cables or busses.

The writer had intended to give the results of some recent tests on large steam turbines as well as to point out the general features of water power plant and gas engine station design, but as this paper is already beyond the imposed limitations these subjects will not be dealt with.

In closing it might be interesting to point out the general features of one of the recent large turbine stations. In the Quarry street station of the Commonwealth-Edison Co. the boiler settings are of the so-called marine type, the stoker being placed at what is usually the rear of the boiler. This will undoubtedly give better combustion, less smoke and a higher efficiency. As the largest steam turbines now approach the economy of internal combustion engines the improvement in steam apparatus then must lie in the steam boiler. The prevention of smoke in a power plant located in the heart of a great city is not only desirable but almost compulsory. In this new furnace the gases driven off by the first combustion have time to come in contact or pass through the hotter flames in the rear before coming in contact with the relatively cold boiler tubes.

The problem of proper ventilation of the generator has here received due consideration for the first time in this type of unit. A large air pipe connects an air duct in the basement with the top of the generator, the revolving field being provided with vanes which draw the air from the duct through the pipe and discharge it, through openings in the frame, into the turbine room.

The electrical end of the station is designed with due consideration for protecting life as well as guarding against material accidents. The oil switches are equipped with disconnecting switches which allow them to be cut entirely free. A signal board is installed in the oil switch room indicating which lines are alive.

There is one point here that the writer would like to impress clearly upon the mind of the reader, and that is the importance of protecting human life in engineering design. We have a great deal to learn from foreign engineers in this respect. The installation of open, high-voltage wires where attendants can come in contact with them in the performance of their regular duties is only one of the many death traps that is permitted. After all, the highest sense of duty in engineering is the lending of a helping hand to fellow man, and every possible precaution should be taken to guard against loss of life in engineering design.

MANUFACTURING SMALL GAS ENGINES.

BY E. B. CUSHMAN.

The manufacturers of gas engines have, to a great extent, put their best material and workmanship into the larger size motors of the four-cycle type, and constructed the smaller sizes of the two-cycle type with as little work and as cheap material as possible in order to supply the demand for a small, low-price motor. All this tends to prejudice the public against the two-cycle principle.

The company with which the writer is connected believed that it was possible to build a two-cycle motor that would not only develop more power than the four-cycle and show as much flexibility, but due to its simplicity, show a much lower maintenance cost. The company placed on the market six years ago a two-cycle, high-speed motor from which there has been but little change since, with the exception of a few minor details.

After purchasing castings from different foundries from Chicago to Denver, with anything but satisfactory results, we began to realize what the manufacturer in this locality was really up against. At that time there was not a single foundry west of Chicago that was making a specialty of small gas engine cylinder castings, with the exception of a few manufacturers who were making them for their own use. Therefore high-class work in this line could not be obtained, so a small foundry of our own was erected, which has given most gratifying results.

Small gas engine cylinders, where the cylinder, water jacket, head, transfer port, feed and exhaust chambers are cast integral and so designed as to be of maximum strength, with a minimum amount of material, are to the foundry a separate branch by themselves, and require no small amount of care, skill and judgment to produce a heat of perfect castings.

Illustration No. 1 shows an open mould for a two-cycle cylinder with cores in place. The sand used in these cores is of a mixture of Platte river and Ohio moulding sand with boiled oil as a binder. The venting of the main core is done in the usual way by means of a vent rod while the core is green. The jacket and other thin cores are of such a shape that it is im-

possible to accomplish the venting in this manner, so wax tapers are used. The wax is carefully tested before going into cores, as the proper results depend very much on the quality of wax used. For instance, some grades of wax may work nicely in the core until they are melted out during the baking process, then they make the entire core so soft and rotten that it cannot be used.

Cut No. 2 shows a cross section of a finished cylinder of the four-cycle type. The cylinder walls are one-quarter of an inch in thickness, while the water jacket and valve chamber walls are cast less than three-sixteenths of an inch. In the casting of stove parts even thinner castings than this are made, but in so doing there is but one end in view, viz., sound, smooth castings, and any kind of material that will produce a casting of this kind is all that is necessary; but in cylinder casting there are four vital points that must be taken into consideration: First, the casting must be sound and free from flaws; second, it must be close grained in order to take a high finish and wear well; third, it must be high in tensile strength, and fourth, it must be of sufficient softness to machine easily. All of these qualities are not to be found in any of the Northern or the Southern rivers alone, but require a mixture of Lake Superior and Southern iron to produce the best results.

BORING AND GRINDING OF CYLINDERS.

The cylinder is caught in a special jig designed to suit the shape of the cylinder and is bored by means of a boring bar with a single tool to within .006 of size very much the same as any internal boring would be done on a lathe. After this operation, without removing the cylinder from the jig, the boring bar on the turret is swung out of place and a carborundum wheel of about three-fourths the diameter of the cylinder is brought in position. This wheel is carried on a hardened tool-steel shaft, accurately ground, running in white bronze bearings and is driven by means of a belt from a drum over the machine. A stream of water is fed to the wheel while in the cylinder so as to keep the work at a uniform temperature and thus do accurate grinding. The machine is equipped with a micrometer dial graduated. The operation is held to limit .001 variation. The question is often asked, "How about the wear of the carborundum wheel, why does this not wear off

and cause the cylinder to taper?" In reply to this, we cannot say just what the wear is on the wheel, but we do know that one wheel will grind about two hundred cylinders and only be reduced in size about one-eighth of an inch, and that a greater part of this is due to the dressing, and that the cylinders do not show a taper of more than .0005, and some in one direction and some in the other, proving that the wear of the wheel had nothing to do with the taper. This method of cylinder finishing not only produces a smooth, highly-polished surface and an accurate bore but greatly increases the efficiency and durability of the motors.

Cut No. 3 shows some of the parts in detail. The exhaust and feed valves are both mechanically operated by the same cam. The raise on the cam pushes the exhaust open. After it has closed the roller on the push rod drops into an indentation which pulls the feed valve open. Between the closing of the exhaust valve and opening of the feed valve the push rod comes to rest for about eight degrees, thus making the valve action noiseless. The feed valve which is directly over the exhaust is mounted in a cage that can be easily removed. The exhaust valve is made with a nickel steel head electrically welded to a carbon steel stem, after which the entire valve is ground. The head being of nickel steel prevents the oxidization and pitting of the seat.

The push rod is made of machine steel. After rough turning and milling it is placed in a carbonizing furnace, where it remains for about ten hours. This carbonizes the entire surface to the depth of three thirty-seconds of an inch. They are then allowed to cool slowly, after which they are straightened, reheated and hardened, then ground to size. The push rod and pin are of tool steel hardened and ground.

The crank shaft is drop forged of a special steel. After being rough turned, the center of the shaft is placed in a cast iron box, allowing both ends to project. Bone black and charcoal are then tightly packed around the crank pin, a cover placed over the box and all of the joints stopped with fire clay. The boxes are then placed in the carbonizing furnace for twelve to fourteen hours. After coming out they also require straightening before hardening. After hardening, the entire shaft is ground to size.

This method of hardening crank pins has been adopted only

by a few manufacturers of high-class automobiles, yet the increased durability of a hardened bearing pays for the extra cost of so doing several times over. On a certain test made in our own factory a double cylinder motor having one crank pin hardened and the other not, was run for about six months with full load and at about twice its normal speed. This motor was used for power purposes ten hours per day and for electric light service about three hours. When the test was completed, the motor was taken apart and the bearing measured up. The crank pin which had not been hardened was worn out of round .007 of an inch. The phosphor bronze boxes also wore away about .10 of an inch, while the same grade of bronze on the hardened pin was worn away only .005" and the pin itself was out of round only .001.

Cut No. 4 shows a three-horse-power, four-cycle, stationary motor. The governor, which is enclosed in a crank case and runs in oil (as do all the working parts), is of the throttling type. This particular motor develops $3\frac{1}{2}$ to 4 H. P. and weighs 165 pounds complete.

Cut No. 5 shows a 14 H.-P. marine motor which is of the two-cycle type.

CRANE GIRDERS FOR ELECTRIC TRAVELING CRANES.

BY T. B. DAVIS, '06.

EDITOR'S NOTE.—The author of this article furnished the Blue Print with eight views showing various parts of traveling cranes, but as the book had already gone to press it was too late to have the views printed.

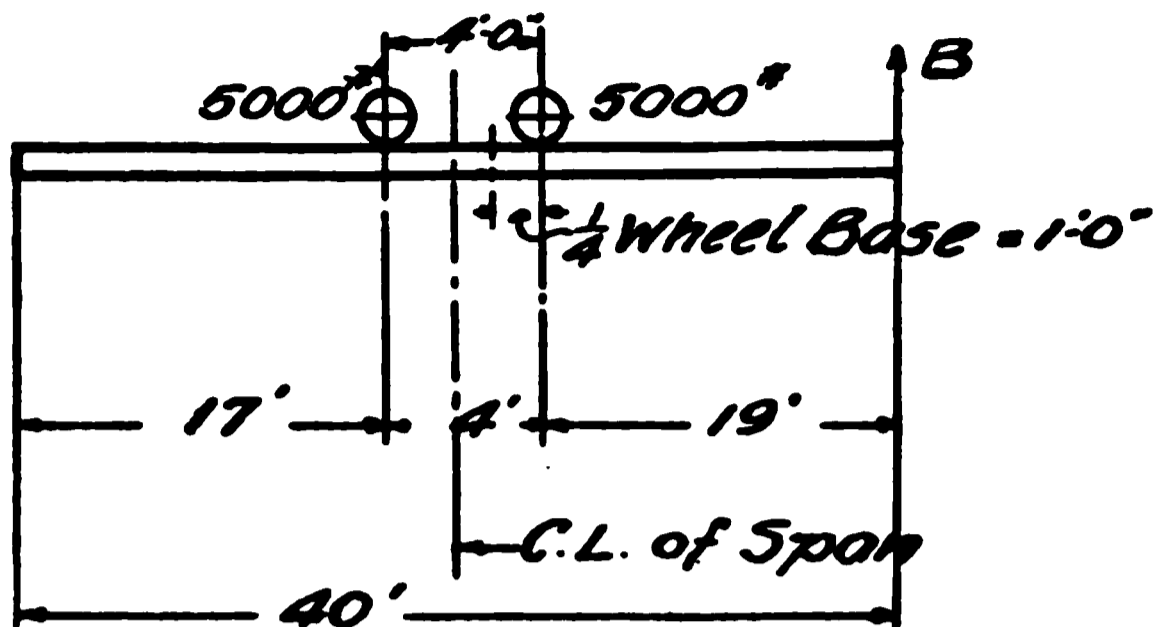
I-beam girders with channel stiffeners on top flange.

The I's should carry the whole vertical load and the channels care for the horizontal side thrust due to starting and stopping the crane. The width of the channel cover can reasonably be taken as the flange width as affecting the lateral flexure of the beam.

If l = span in inches and b = width of flanges in inches, $\frac{l}{b}$ should not be greater than 50, and allowed unit stresses shall be as given in table of allowable fibre stresses due to lateral flexure.

| Ratio of span to flange width $\frac{l}{b}$ | Allowable unit stress for direct flexure in extreme fibre P | Proportion of safe tabular load to be used |
|--|--|--|
| 19.37 | 16,000 | 1.0 |
| 20 | 15,882 | .97 |
| 25 | 14,897 | .93 |
| 30 | 13,846 | .87 |
| 35 | 12,781 | .80 |
| 40 | 11,739 | .73 |
| 45 | 10,746 | .67 |
| 50 | 9,818 | .61 |
| 55 | 8,963 | .56 |
| 60 | 8,182 | .51 |
| 65 | 7,474 | .47 |
| 70 | 6,835 | .43 |
| 75 | 6,261 | .39 |

For Bending—Assume a 40' span of bridge. Trolley wheel base = 4'; weight of trolley and load = 10,000 pounds uniformly distributed on four trolley wheels.



$$\text{Reaction at Support B} = \left. \begin{array}{l} \frac{21}{40} \times 5,000 \text{ lbs.} \\ \frac{17}{40} \times 5,000 \text{ lbs.} \end{array} \right\} = 4,750 \text{ lbs.}$$

The max. bending moment = $4,750 \times 19 \times 12 = 1,083,000''$ lbs.
 Allow 25 per cent for impact..... 270,750

Total bending moment due to live load.... 1,353,750'' lbs.

If we use a 10" channel cover, $\frac{l}{b} = \frac{480}{10} = 48$, and safe load = .64 tabular load.

The equivalent load at full tabular values = $1,353,750''$ lbs. \div .64 = $2,115,234''$ lbs.

Allowed fibre stress for live load = 11,500 lbs.

$$\frac{2,115,234}{11,500} = 183.9 \text{ section modulus required for live load.}$$

Try 20" — 65 lbs. I's with 10" — 15 lbs. channel covers and 40 lb. rails, the weight of the bridge = $40 (65 \text{ lb. I} + 15 \text{ lb. chan} + 14 \text{ lb. rail}) \times 2 = 7,520$ lbs.

$\frac{1}{8} \times 7,520 \times 40 \times 12 = 451,200''$ lbs. bending due to dead load.

$451,200 \div 16,000 = 28.2$ section modulus required for D. L.

183.9 section modulus required for L. L.

212.1 total section modulus required.

Use 2 — 20" — 65 lb. I's..... $S = 234$.

An additional stress is imposed upon the channel cover, due to stopping the travel of the crane when moving at full speed on the runway. It is generally customary to assume a coefficient of

friction of .25 between the track wheel and the rail, and since the total load of the crane is carried on four wheels the load on the two driving wheels will be one-half of the sum of the live and dead loads.

The maximum bending moments in the lateral plane will occur when the trolley is in the middle of the girder and the foot brake is applied, which will make the track wheels skid on the rails.

In the case assumed the friction amounts to $\frac{1}{4}$ of $\frac{10,000}{2} = 1,250$ lbs.

The bending moment due to the concentrated live load = $\frac{1}{4} \times 1,250 \times 40 \times 12 = 150,000''$ lbs.

The horizontal bending moment due to the weight of the girders is equal to $\frac{1}{8} \times \left(\frac{1}{4} \times \frac{7500}{2} \right) \times 40 \times 12 = 56,250''$ lbs.

The total bending moment is equal to $150,000''$ lbs. + $56,250''$ lbs. = $206,250''$ lbs.

The total bending moment, $206,250''$ lbs. $\div 11,500$, the allowable fibre stress, is equal to 17.9 section modulus required for side deflection for both girders; which would require 2 — 10" 15 lb. channels with a total section modulus of 26.8.

BOX GIRDERS FOR ELECTRIC TRAVELING CRANES.

In a plate or box girder the top flange is subject to compression and the bottom flange to tension. It is customary in practice to make both flanges equal, and composed of the same size of plates and angles. In proportioning the flanges of girders the lower flange is calculated for tension; the areas of the rivet holes cut out of the flanges are deducted from the total area so as to give the net or actual area of the flange at the point of least strength. The stresses in the flange are assumed to be produced wholly by the bending moment on the girder and the moments of these stresses are assumed to be equal to the moments of the external forces. The maximum bending moment due to the live load—consisting of the trolley and material being handled—occurs when one wheel of the trolley is one-fourth of the wheel base of the trolley to the right or left of the center line of the girder. Knowing the total live load and the span, the reactions can easily be determined and the maximum bending moment due to the live load can be found (see sketch attached which applies to any girder). The dead load, which consists

of the girder, together with traverse shaft, boxes and runway rail for the trolley, must be assumed as the bending moment due to a distributed load is equal to $\frac{Wl}{8}$. W = weight; l = length of span in inches; 8 is a constant.

The area of the flanges for two girders is equal to the sum of the bending moments due to the live load divided by the depth of the girder in inches multiplied by fibre stress per square inch of material, or expressed in the formula:

$$A = \frac{M}{Df}$$

in which A = net area of two flanges in square inches.
 D = depth of girder in inches.
 f = safe fibre stress per square in. of material.
 M = Bending moment of the girders in whole pounds.

While plate girders are more economical than box girders, the latter are stiffer in the lateral direction and hence should be used where a wide-top flange is required in order to furnish the necessary lateral stiffness for a long span. If the girder is not held in place laterally the top flange should have the width equal to one-twentieth of the span. Otherwise the gross area of the top flange may be found by the following formula:

$$A' = A \left(1 + \frac{l^2}{5000} \right)$$

in which A = gross area required in top flange with the girder supported laterally.
 A' = gross area in top flange with the girder unsupported laterally.

ADOPTED DEPTH.

It has been found by experience that the most economical depth for crane girders carrying a load of from one to one hundred tons, and with spans from 30 to 120 feet, is one-fifteenth to one-twentieth of the span.

DISTRIBUTION OF RIVETS IN FLANGES.

The pitch of the rivets in the flange angles of web plate is usually determined by computing total flange stress at intervals along the beam and dividing the stress increments in the flange by the distance of one rivet.

Let S = shear on the section.

p = pitch of the rivets in the flange angles.

r = resistance of one rivet.

h = distance between rivet lines in top and bottom flanges.

w = vertical load on the flange per lineal inch.

F = area of one flange.

A = area of web.

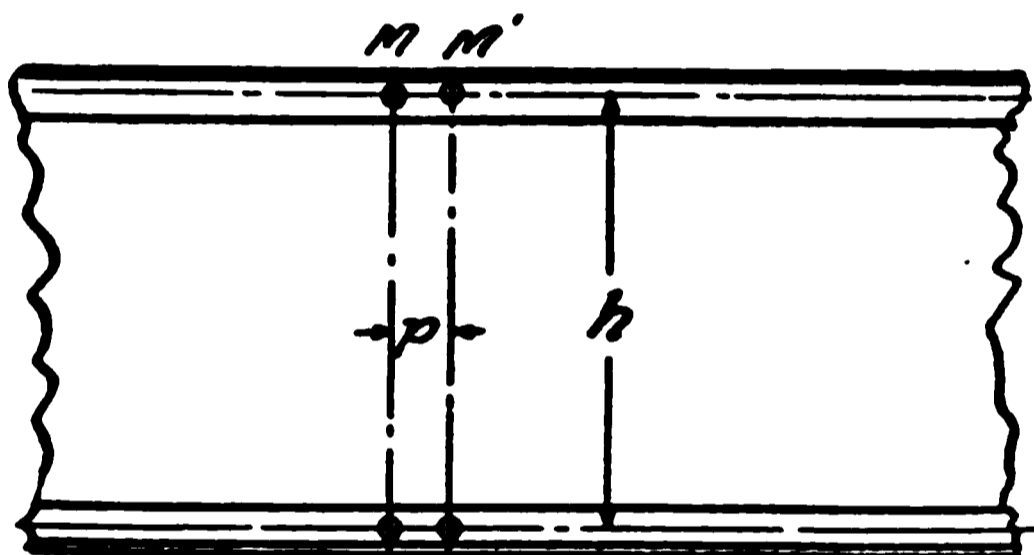
In case the vertical load is supported by the flanges, as is usual in crane girders where the rail rests on top of the cover plate, the rivets connecting the flange to the web receive a vertical stress in addition to the horizontal shear, and the pitch must be reduced accordingly.

Assuming first that all moment is resisted by the flanges, the horizontal stress on each rivet would be $\frac{Sp}{h}$. The resultant stress would then be:

$$r = \sqrt{(pw)^2 + \left(\frac{Sp}{h}\right)^2},$$

from which

$$p = \frac{r}{\sqrt{w^2 + \left(\frac{S}{h}\right)^2}}.$$



Some designers prefer to assume that one-eighth of the area of the web is effective in resisting the bending moment; in which case the above formula becomes:

$$p = \frac{r}{\sqrt{w^2 + \left[\frac{F}{F + \frac{A}{8}} \times \frac{S}{h} \right]^2}}$$

The load is assumed to move from the end toward the center and the rivet spacing at intervals of about 4' usually suffices for all practical purposes, and the spacing between any two given points is made the same.

THE AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS.

BY J. B. DAVIDSON, '04.

In December, 1907, some fifteen or twenty instructors in agricultural engineering and farm mechanics, from the various state educational institutions throughout the country, and several representatives of commercial firms met at the University of Wisconsin to discuss the various problems before those engaged in these lines of work. As a result of the enthusiasm of the meeting the American Society of Agricultural Engineers was organized. A year later the first annual meeting was held at the University of Illinois, and with about the same number of college men in attendance, but with many more representatives of the implement and farm machine industry and the technical press. To those who have not been connected with this new society of engineers it may be interesting to learn something of its objects and its plans. This paper will be a brief discussion of the same, being in part portions of the first annual address before the society.

The objects of the American Society of Agricultural Engineers, as set forth in the constitution, are to promote the art and science of engineering as applied to agriculture. The principal means of promoting this purpose shall be by the holding of meetings for the reading and discussion of professional papers and for social intercourse; and the general dissemination of information by the publication and distribution of its papers and discussions.

The past decade has witnessed a wide extension of engineering into agriculture that is almost beyond comprehension. Engineering has come to the farmer to make farming one of the most desirable of all vocations. It is engineering that has been one of the chief factors in raising agriculture to the high standard that it has attained. This has been brought about by machinery utilizing power other than human power, by better farm buildings, better field and sanitary drainage, more adequate water supply, improved methods of securing and applying irrigation water and good roads—all phases of engineering. From the scope of agricultural engineering it is evident that it fills

an important place in modern agricultural endeavor. This has been recognized by nearly all of the leading agricultural colleges of the country, since they have established courses, and in most cases departments for agricultural engineering instruction. So sudden and exacting are the demands for expansion in this direction that in many cases the extension of the work has exceeded the literature on the various subjects. If the society is to fulfill its purpose in the largest way it must assist in collecting and furnishing reliable agricultural engineering data, not only to college instructors but also to those engaged in professional engineering endeavor. No doubt one of the first lines of work to be undertaken by the society should be to obtain a complete and accurate bibliography of all agricultural engineering literature.

This search of the world's literature, together with the papers presented to and published by the society from time to time, as provided for by the constitution, will be a work and an object worthy of any scientific body and should be of benefit to mankind and as such should be commended.

Another object of the society, as set forth in the constitution, is to enable its members to meet in a social way and encourage good feeling among all engaged in the profession. In looking over the history of the early attempts to form engineers' societies, it was noticed that one reason given for their failure in accomplishing their purpose in the fullest way was the absence of any means of promoting the social interest of the members. The value of the beneficial influence of having the members of the profession meet together and gain the enthusiasm and inspiration which is sure to be received by all in such a meeting cannot be over-estimated. All of the older engineers' societies look well after the social features of each meeting.

The society has an important field in designating and emphasizing the importance and value of the work of the agricultural engineer. By presenting a solid front to the world, the members will not only be able to advance themselves but also render the world and humanity a commendable service worthy of any organization. Agricultural engineering instruction in the colleges is only in its infancy, and the society should be a factor in establishing definitely the science, theory and practice of agricultural engineering. With a good training in agricultural engineering the agricultural worker will be better equipped to cope with the world's problems. The engineering training

demanded today in the successful management of a modern farm, as well as a thorough knowledge of engineering subjects, is absolute evidence that agricultural engineering must and will be given a more important place in the agricultural college curriculum.

The work of the American Society of Agricultural Engineers must be largely educational, for not only must the science of agricultural engineering be developed but its practice must be given to the world. As soon as better homes, better and more improved machinery, more complete and refined drainage and irrigation systems, and better highways are demanded by the people in general, in like proportion the prosperity of the nation and its agricultural engineers will advance.

Perhaps the argument will be advanced that all phases of agricultural engineering are included in the present societies. The American Society of Civil Engineers will include the work of the drainage, irrigation and highway engineer; the American Society of Mechanical Engineers the work of the farm implement designer, and the Architects' Society the work of the designer of farm buildings. It is true that the new society must offer more than the older society, for if not there will be no inducement for engineers to become members of the new. If the new society is to fill its proper place at all, it will be able to offer much more to its members than all of the older societies put together if it were possible to be a member of them all. Engineering has become such a complex subject and has reached such a high stage of development in the older branches that agricultural engineering is practically excluded. An examination of the later proceedings of the societies referred to will prove the above statement.

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EDITORIALS.

THROUGH the persistent efforts of Dean Richards the new engineering building will be completed and fully equipped for work by next fall. Dean Richards has made a careful study of the buildings and equipment in a majority of the better institutions of this country and when completed the new building which was designed by him will be at least the equal of any similar structure in the United States in design, convenience, arrangement and equipment.

THE development of engineering at the University of Nebraska has been very gratifying to those interested in the work. In spite of "stiff" courses, and a lack of adequate room, equipment and instructional staff, the number of students has steadily increased. With the completion of the fine new mechanical engineering laboratory and the readjustments made possible by the completion of this building, the work of the college of engineering will become more thorough, interesting and effective. The completion and equipment of the new building is but the beginning of a program of betterment which it is hoped may be carried out within a very few years.

WE are only voicing the desire of every Nebraska engineer when we say that it is our desire to make the BLUE PRINT a better book from year to year. To do this we must have the cooperation of the alumni members who in the past have aided so generously toward making the BLUE PRINT what it is; but we refer here particularly to suggestions. We will be glad to receive any suggestions that will tend to make the BLUE PRINT a better book.

ANOTHER matter we wish to bring before the alumni is that it is becoming more difficult from year to year to procure the desired number of articles for the BLUE PRINT, owing to the fact

that our list of contributors of articles is increasing, and some of the men are contributing articles for the second and third time. If any member of the alumni has a good article or knows of some other member who has he would do us a great favor by advising us accordingly.

THE ENGINEERING SOCIETY.

The society was organized to promote engineering fellowship, to give the engineering departments more prominence, and to provide from time to time pleasing and instructive entertainments for the public. Since its organization nine years ago the society has made rapid progress, and is today the largest and one of the most successful societies in the university.

Last year an associate membership was established, and now a student cannot become an active member of the society until he has been an associate in good standing for four months, and has made at least ten hours credit in the college of engineering. This has raised the standard of the society. Any engineer is eligible to associate membership.

A number of addresses have been given before the society this year as follows:

"Gas Engineering," by W. Bradford, General Superintendent Lincoln Gas and Electric Light Co.

"The Place of Engineering Science in the World," by Dr. Howard.

"Wages, and the Various Systems of Paying," by Dean Richards.

"Concrete in Old Roman Architecture," by Prof. G. E. Barber.

"The Manufacture of Portland Cement," by C. W. Boynton, Inspecting Engineer of the Universal Portland Cement Co.

Several short talks were also given as follows:

"Direct Current Switch-Boards," by A. L. Harvey.

"Experiences while with a Wiring Gang," by H. C. Currier.

"The Drafting Room," by M. E. Strieter.

The society also gave its annual hop last fall, and two smokers were given which proved to be very successful.

This closes the program to date, but the annual banquet will be held in the near future and negotiations are on for two more good lectures before the end of the year.

HONORARY MEMBERS.

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|--------------------------|-------------------------|
| C. R. Richards, M. M. E. | C. L. Dean, B. Sc. |
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| G. R. Chatburn, A. M. | A. Boyd, B. Sc. |
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| C. E. Mickey, B. Sc. | J. E. Rasmussen, B. Sc. |
| P. K. Slaymaker | |

OFFICERS OF THE SOCIETY.

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| W. C. HUTCHINSON..... | Treasurer |
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| E. R. Pelster | H. T. White | H. S. Villars |
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| A. A. Nielsen | K. Megenee | J. R. Wason |
| H. P. Letton | V. E. Friend | C. J. Harden |
| H. O. Baumann | V. P. Villanueva | W. N. Bozarth |
| F. S. Wiles | E. R. Levin | J. A. Balderson |
| H. H. Plumb | R. W. Queal | J. P. Burke |
| W. E. Byerts | H. L. White | C. Collins |
| F. Harding | C. Dewald | E. A. Schmid |
| N. M. Collier | W. A. Kelly | H. S. Gow |

ASSOCIATE MEMBERS.

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| A. E. Ingersoll | G. L. Guthrie | F. E. Rohde |
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| P. L. Ernst | H. F. Smith | R. Dunlay |
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| C. N. Kessler | R. A. Haggart | C. Cook |
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| R. E. Davies | R. L. Tock | H. Cain |
| W. E. Dorland | J. H. Goodnough | R. L. Cochrane |
| C. G. Bolibaugh | J. C. Phillips | D. Ericson |
| C. G. Perry | C. D. Merritt | P. E. Griswold |
| G. L. Porter | M. Erildon | O. C. Montgomery |
| C. Spellmeyer | S. A. Swanson | H. La Chapelle |
| H. Raymond | J. L. Ward | L. Cottromen |
| V. Harrington | W. J. Lempke | D. D. Plumb |
| G. Armstrong | L. Arbs | H. S. Nixon |
| A. Luebo | L. Biddlecomb | O. E. Vanberg |
| J. Hollings | L. D. Walters | G. R. Le Roy |
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| V. White | I. L. Woods | G. J. Moss |
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| J. A. Hepperlen | | |

UNIVERSITY OF NEBRASKA BRANCH
OF THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

The American Institute of Electrical Engineers represents the largest organized body of scientifically trained electrical workers. As a representative body of American genius and industry it has raised the standards of the electrical profession socially and economically. Electrical engineers are no longer confounded with linemen and laborers; they rank as investigators and engineers among the brightest intellects. Socially the electrical engineer is known and given high standing. The services rendered to man by the varied applications of electricity are almost innumerable and give employment to a vast army of workers. Pursuing its policy of raising the standard and increasing the value of the electrical worker the American Institute has authorized the formation of sections and branches.

Sections are local organizations of electrical engineers, members of the national body, formed for the purpose of affording a meeting place for and bringing into close relationship co-workers and co-interests.

Branches are sections formed at the various institutions teaching the subjects pertaining to the electrical profession. They are for the benefit of the students. The meetings held under the direction of the faculty of such institutions and local representatives of the electrical fraternity are at once an encouragement, an incentive to learn and a training in the work selected by the student as his profession. The national body supports financially, to a limited extent, the activities of the branches. Reports of local meetings, items of interest, together with lists of officers are published in the proceedings of the parent organization. The students pay only nominal dues for the privileges they receive. They are entitled to hold minor offices in the branches, receive the publications of the national organization and may become associates or full members upon election and payment of increased dues.

It is under such liberal patronage that the University of

Nebraska Branch of Electrical Engineers is organized. The benefits accruing to students and members have strengthened the local branch immeasurably. Its sphere of influence is enlarging at a rapid pace. The meetings of the past year, with addresses delivered by B. C. Adams of the Lincoln Gas and Electric Company, B. W. Capen of the Nebraska Telephone Company, Professor George Hart Morse, and others, have created interest and a demand that the University of Nebraska Branch of the American Institute of Electrical Engineers extend its work and activities.

ALUMNI DIRECTORY.

This directory contains the names of all the graduates of Engineering Courses from the University, also a few graduates of other courses who have taken up engineering work, and a few who have left school before graduation and are engaged in engineering work. The addresses have been corrected to the best of our knowledge to date, March, 1909. The editors will be pleased to receive any corrections or additions to be filed for the use of their successors.

- Abbott, M. D., B. Sc., E. E., '08. Lincoln, Neb.
Abel, G. P., B. Sc., C. E., '06. Lincoln, Neb., Eng. Dept. C., B. & Q. R. R.
Akerlund, F. R., B. Sc., M. E., '06. Valley, Neb.
Albers, Jurgen, B. Sc., C. E., '93.
Allen, R. N., B. Sc., E. E., '08. Meter Dept. Seattle Electric Co., 533 Y. M. C. A., Seattle, Wash.
Anderson, E. E., B. Sc., C. E., '05. Lincoln, Neb., Ass't Supt. of Construction, U. of N.
Arnold, Bion J., E. E., '98. 181 La Salle St., Chicago, Ill., President of The Arnold Co.
Bailey, B. P., '93. Okmulgee, Okla., Electrician.
Baker, L. N., B. Sc., M. E., '07. Beatrice, Neb.
Barks, F. S., '03. 1629 Pierce Building, St. Louis, Mo., with Commonwealth Steel Co.
Barkley, J. A., B. Sc., C. E., '92. Gen'l Mgr. Port Elizabeth Tramway, Port Elizabeth, Cape Colony, So. Africa.
Bates, G. W., B. Sc., C. E., '05. 327 No. 31st St., Lincoln, Neb., Sec'y State Board of Irrigation.
Battan, R., B. Sc., C. E., '07. S. 175 Howard St., Spokane, Wash., Vice-Pres. Amer. Concrete and Eng. Co.
Bay, Burt, B. Sc., E. E., '06. Westinghouse Sales Dept., Riverton, New Jersey.
Beardslee, C. O. Lincoln, Neb.
Bedell, C. E., B. Sc., E. E., '00. Pittsburg, Pa., Designing Eng. Westinghouse Mfg. Co.
Belden, C. E., B. Sc., E. E., '07. Dawson, Neb.
Belnap, L. J., B. Sc., E. E., '98. Montreal, Canada, Montreal Manager Allis Chalmers Co.
Benedict, B. W., B. Sc., M. E., '01. 630 Lane St., Topeka Kan., Supervisor of Schedules, Santa Fe System.
Benjamin, W. E., B. Sc., C. E., '96. Cheyenne, Wyo., Deputy Co. Clerk.

- Berquist, H. B., B. Sc., C. E., '08. 1306 No. 25th St., South Omaha, Neb., Coal and Grain Business.
- Bessey, E. A., B. Sc., E. E., '98. Denver, Colo., Denver Electric Co.
- Bessey, C. A., B. Sc., E. E., '99. Chicago, Ill., Sargeant & Lundie.
- Biggerstaff, C. D., C. E., '01. Golden, Colo., Instructor in the Colorado State Industrial School for Boys.
- Bliss, E. F., B. Sc., E. E., '02. Schenectady, N. Y., General Electric Co.
- Bolles, C. M., B. Sc., E. E., '06. Box Elder, Neb.
- Bowlby, H. L., B. Sc., C. E., '05. Seattle, Wash., Instructor in C. E. Uni. of Washington.
- Brackett, E. E., B. Sc., E. E., '01. Philadelphia, Pa., Instructor in E. E. Uni. of Penn.
- Brigham, E. W., B. Sc., E. E., '06. Schenectady, N. Y., General Electric Co.
- Brooke, I. E., B. Sc., E. E., Chicago, Ill. The Arnold Co.
- Brooke, W. E., B. Sc., C. E., '92. Minneapolis, Minn., Uni. of Minn.
- Brooks, G. W., B. Sc., E. E., '02. Schenectady, N. Y., Construction Foreman, Gen. Elec. Co.
- Brown, A., B. Sc., '03. Aurora, Neb.
- Brown, G. F., B. Sc., '04. 785 State St., Schenectady, N. Y., General Office General Elec. Co.
- Brockway, P. L., B. Sc., C. E., '05. 803 So. Water St., Wichita, Kan., Civil Engineer.
- Bruce, J. A., B. Sc., '03. Eng. Dept. U. P. Ry.
- Bryan, C. H., Cedar, Colo., Chem. Eng.
- Buckley, N. E., B. Sc., '03. 914 So. 26th St., Omaha, Neb., Asst. Eng. U. P. Ry.
- Buckstaff, F. B., B. Sc., '03. Chicago, Ill., Estimator, Henry Pratt Boiler & Machine Co.
- Burkey, C. R., A. B., B. Sc., C. E., '06. Jerome, Idaho., Chief Draftsman, "Twin Falls North Side Land & Water Co."
- Burr, F. D., B. Sc., E. E., '02. Hawserlake, Mont.
- Campbell, S. C., B. Sc., M. E., '02. Rock Hill, S. C., Mgr. Rock Hill Ice Co.
- Carter, A. E., B. Sc., C. E., '99. C. E. Columbia Uni., 449 W. 123d St., N. Y. City, Res. Eng. Rapid Transit Subway Co.
- Case, M. B., C. E., '04, B. Sc., C. E., '06, Illinois Uni. Ass't Eng. Vancouver-Portland Bridges, 510 Ravine Ave., Peoria, Ill.
- Charles, E. D. Wisner, Neb., City Electrician.
- Chase, L. W., B. Sc., M. E., '04. 1245 No. 33d St., Lincoln, Neb., Prof. Farm Mechanics, Uni. of Neb.
- Chessington, J. B., C. E., '04. Thermopolis, Wyo., City Engineer.
- Christensen, W., '00. Utah, Mercur Mining Co.
- Clinton, S. D., B. Sc., C. E., '02. Chief Engineer, Downey, Idaho.

- Cole, C. L., B. Sc., M. E., '06. 3920 Lake Ave., Chicago, Allis-Chalmers Co., Milwaukee, Testing Dept.
- Collet, A. J., B. Sc., M. E., '00. Omaha, Neb., Electrical Engineer Union Pacific Railroad Co.
- Cornell, C. B., B. Sc., E. E., '04.
- Corr, Ray, B. Sc., M. E., '04. Indianapolis, Ind., Atlas Engine Works.
- Cortelyou, S. V., B. Sc., C. E., '02.
- Costelloe, M. F. P., B. Sc., C. E., '06. Fort Morgan, Colo., Civil and Irrigation Engineer.
- Cramer, D. L. Dutchcreek, Nev., Mining Engineer.
- Crane, C. O., B. Sc., E. E. Chicago, Ill., Arnold Elec. Power Sta. Co.
- Crook, G. A., B. Sc., C. E., '08. Falls City, Neb., Contractor for Monarch Construction Co.
- Crook, Z. E., B. Sc., E. E., '97. Faribault, Minn., Res. Eng. C., M. & St. P. R. R.
- Crownover, C. E., B. Sc., C. E., '97. 1502 Pacific Ave., Everett, Wash., Locating Eng. G. N. Ry.
- Cushman, C. R., B. Sc., E. E., '02. Lincoln, Neb., Cushman Motor Co.
- Cushall, L. A., B. Sc., E. E., '05. El Paso, Texas, Wire Chief, Southern Independent Telephone Co.
- Davis, C. L., B. Sc., E. E., '06. 811 Franklin Ave., Wilkinsburg Sta., Pittsburg, Pa., Westinghouse Mfg. Co.
- Davis, E. O., B. Sc., C. E., '05. U. P. R. R., Denver, Colo.
- Davis, T. B., B. Sc., M. E., '06. Chief Engineer, Cleveland Crane and Engineering Co., Wickliffe, Ohio.
- Davidson, J. B., B. Sc., M. E., '04. Professor of Agricultural Engineering, Iowa State College, Ames, Iowa.
- Debler, B. E., B. Sc., C. E., '07. Spokane, Wash.
- Day, W. F., B. Sc., C. E., '06. Ass't Eng., J. G. White Co., Richfield, Ida.
- Dobson, Frank A., B. Sc., C. E., '03. Contracting Engineer, Lincoln, Neb.
- Dormann, F. B., B. Sc., M. E., '01. American Bridge Co., Denver, Colo.
- Doulrava, H. W., B. Sc., E. E., '97. Sales Eng. New York Office, Wagner Elec. Mfg. Co.
- Doubt, J. C., Jr., B. Sc., '03. Kilbourne & Clarke Co., Seattle, Wash.
- Doubt, R. A., B. Sc., E. E., '01. Western Elec. Co., New York City.
- Downes, N. W., B. Sc., M. E., '07. Mech. Dept. U. P. R. R., Omaha, Neb.
- Duer, C. B., B. Sc., E. E., '07. Hastings, Neb.
- Dumont, R. E., B. Sc., C. E., '06. Ass't Eng. C. & N. W. Ry., Omaha, Neb.
- Dwyer, R. C., B. Sc., E. E., '07. Apprentice Dept. Westinghouse Mfg. Co., Wilkinsburg, Pa.
- Eagleson, E. G., B. Sc., C. E., '89. U. S. Surveyor General for Idaho, Boise, Idaho.
- Early, J. W., B. Sc., E. E. Consulting Engineer, Columbus, Neb.

- Eaton, B. K., B. Sc., M. E., '08. Omaha, Neb.
Ellis, O. A., B. Sc., C. E., '07. Panama, Neb.
Elmen, G. W., B. Sc., M. E., '02. Development Eng. Physical Lab., Western Elec. Co., New York City.
Elson, T. H., '03. Kearney, Neb.
Elson, W. D. Western Electric Co., Cleveland, Ohio.
Engel, C. W., B. Sc., C. E., '03. C. & N. W. Ry., Farnam St., Omaha, Neb.
Evans, H. S., B. Sc., '98., E. E., '01. Head Professor of E. E., University of Colorado, Boulder.
Everett, C. C. Supt. W. S. Mining Co., Eureka, Utah.
Fairman, F. F., B. Sc., E. E., '06. With Walters Bros., 75 Board of Trade Bldg., Chicago, Ill.
Farnsworth, G. E., B. Sc., C. E., '04. St. Charles, South Dakota.
Farley, L. L., B. Sc., E. E. Bancroft, Neb.
Fenlon, J. A., B. Sc., C. E., '07. David City, Neb.
Forbes, B. E., A. B., '95. Resident Engineer, Costilla Estate Development Co., San Luis, Colo.
Frazier B. R., B. Sc., E. E., '07. 37 Arthur St., Schenectady, N. Y., Apprentice, G. E. Co.
Friedman, S. B., B. Sc., C. E., '06. Ass't Eng. Collins Const. Co., Omaha, Neb.
Fritts, C. B., B. Sc., E. E., '96. Chief Eng. Metropolitan Street Ry., Kansas City, Mo.
Gibbs, J. B., B. Sc., E. E., '05. Engineering Dept. Westinghouse E. & M. Co., 852 Rebecca Ave., Wilkesburg, Pa.
Grant, Wm., B. Sc., C. E., '97. City Engineer, Lincoln, Neb.
Green, J. A., B. Sc., C. E., '04. Supt. of Construction, J. G. White & Co., Richfield, Idaho.
Green, Wm., '98. Kansas City Telephone Co., Kansas City, Mo.
Griggs, C. E., E. E., '97. Gen. Supt. U. S. Consolidated Mining Co., Eureka, Utah.
Grone, E. A., B. Sc., C. E., '08. Fellow in Mathematics, U. N., Lincoln, Neb.
Gutleben, D. B., '00. Gutleben Bros., Contractors, San Francisco, Cal.
Guthrie, R. E., B. Sc., M. E., '08. Lincoln, Neb.
Hagenow, Chas. F., B. Sc., E. E., '00., M. A. Instructor in Mathematics, Armour Institute of Technology.
Hagensick, E. H., B. Sc., E. E., '06. Elec. Dept. U. P. R. R., Omaha, Neb.
Hall, D. C., B. Sc., E. E., '98. 211 Carlton Ave., Brooklyn, N. Y., Electrical Inspector U. S. Navy.
Hamilton, W. G., B. Sc., E. E., '06. Apprentice Westinghouse E. & M. Co., 811 Franklin Ave. Wilkesburg, Pa.

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- Harris, R. S., B. Sc., C. E., '04. Pres. & Gen'l Mgr. Western Contr's Sup. Co., 430 Paxton Bldg., Omaha, Neb.
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- Hartley, Harry K., B. Sc., E. E., '07. Electrician, Anaheim, Cal.
- Hartsough, G. H., B. Sc., B. E. E., '07. Apprentice Westinghouse E. & M. Co., Wilkinsburg, Pa.
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- Hartzell, Walter, B. Sc., E. E., '05. Westinghouse E. & M. Co., Pittsburg, Pa.
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- Mueller, R. S., B. Sc., E. E., '98. 414 Prospect Ave., S. E., Cleveland, Ohio, Dealer in Electrical Supplies.
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 Pepperburg, A. J., '02. New York City Navy Yard.
 Pierce, E. H., B. Sc., E. E. 942 Warren Ave., Chicago, Ill., Western Elec. Co.
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 Robinson, E. J., B. C. E., '84. 1419 D St., Lincoln, Neb., Res. Eng. C., B. & Q. R. R.
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- Sturdevant, W. C., B. Sc., C. E., '03. Payette, Idaho.
- Sullivan, G. L., B. Sc., M. E., '08. Instructor, Uni. of Colorado, Boulder, Colo.
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